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1923—1924.

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A Member shall be an officer or employee of a public or private water works, an engineer, chemist or other person qualified to aid or interested in the advancement of knowledge relative to water works.

An Honorary Member shall be a person of acknowledged eminence in some branch of water supply or of engineering.

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A Junior shall be not less than eighteen years nor more than twenty-five years of age, a student or connected with water supply work.

An Associate shall be either a person, firm or corporation engaged in manufacturing or furnishing materials or supplies for the construction or maintenance of water works.

A Corporate Member shall be either a Water Board, Commission, Company or Municipal Corporation.

The initiation fees and annual dues are as follows:

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This Association has six regular meetings each year, all of which, except the annual convention in September, are held at Boston.

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Photo by The Kimball Studio, Concord, N. H.

PERCY R. SANDERS,
President of the New England Water Works Association,
1923.

New England Water Works Association

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This Association, as a body, is not responsible for the statements or opinions of any of its members.

SOME ADDITIONS TO NEW ENGLAND WATER WORKS PLANTS.

BY ALLEN HAZEN.*

[*Read by Malcom Pirnie, September 19, 1923.*]

I propose to give you to-day a very brief outline of some of the water-works construction in New England and just over the line in New York State, but without going into details.

New Britain.

Several years ago a plan for the development of the water-supply system was worked out on a scale sufficient to serve the city for many years. When carried out this will result in the complete development of the present water resources.

The plan is unusual in that no good storage site was found to which most of the water would come in a natural way. The plan is to build a large impounding reservoir on an excellent site but with a very small catchment area, and to take the major part of the flood flows from the other areas to it. In this way a practicable scheme was worked out for complete development of these valuable resources. The cost of carrying out even the first installment of this program will be large, and postponement as far as it can be done with safety will make the financial arrangements easier.

In making borings for dam sites, great masses of sand were found in one of the valleys. To build a dam on this sand was impracticable, but it was thought that it might be possible to develop a ground water supply in this location, taking advantage of the natural underground storage in this valley. In this way an addition to the water available in dry times could be obtained that would permit the construction of the main storage reservoir to be postponed for several years.

Some of the works built in this way could be arranged to be part of the permanent construction, but any of it that it might be necessary to discard in future development would have been more than made good in the saving in interest on the cost of the delayed construction.

* Consulting Engineer, New York City.

Accordingly, the city authorized the construction of an underground supply of this kind, and the work has been carried out and the supply tested during the present season. There are twenty wells, 8 in. in diameter, averaging 40 to 45 ft. deep. The position of the wells was determined, first, by very numerous test borings; and second, during construction by pulling up and discarding all wells that did not show favorable results in actual tests. Every one of the twenty wells is therefore believed to be a good one. The Cook strainers are 15 ft. long, 8 in. in diameter, and the slots for the most part are 0.05 in. wide, but some of them are 0.06 in. The slot opening was made as great as the sand would stand. In a few instances, sand was encountered so fine that it continued to come into the wells in quantity, and these wells were abandoned and the strainers pulled. In most cases a considerable quantity of sand entered the well in the early testing and was pumped out until a condition of stability was obtained.

In this testing, an arrangement was used for giving violent back-and-fourth agitation in connection with the pumping, and this was continued until the water came continuously clear and until all fine sand had been removed from the bottom of the well.

The water from these wells is taken into a caisson well, which is covered, 50 ft. in diameter and 30 ft. deep, which itself on test yielded about 1 m.g.d. The use of this well is to insure the entire absence of sand and air in the water taken by the pump.

In driving the wells a 12-in. casing was first driven to the full depth. The strainer and permanent well pipe were placed in it and the 12-in. pipe was then drawn. Sometimes coarse sand was placed in the space before drawing the 12-in. pipe. Independent 4-in. suctions are used in each well, and the connections are arranged so that each suction can be easily removed and the well tested and cleaned, and this can be done with the well shut off and with the rest of the plant in service. A concrete box is built about the head of each well, giving convenient access to facilitate these operations and to exclude surface water. The main suction pipe, laid well below the ground level is of cast-iron pipe with bell joints, calked with lead wool by a pneumatic hammer, and made absolutely tight under air pressure. This is laid with a very slight upgrade to a summit after passing which it drops almost to the bottom of the caisson well, acting as a siphon when the water level is depressed. An air pump attached to the highest point keeps it clear of air.

The water is pumped by a horizontal duplex pump driven by a 150 h.p. Diesel engine. It has a capacity of 3 m.g.d. against a head of 250 ft.

The plant has been able to operate continuously at capacity during the present very dry season, and its use has perhaps prevented a water shortage in New Britain. The water is clear, cool, soft and free from iron.

The cost of the new works has been very moderate. The bills are not yet all paid. Present indications are that, including land and all expenses, it will not exceed $175 000.

Mr. Joseph D. Williams is City Engineer and has immediate charge of the construction work. Mr. Charles R. Bettes, who has had long experience in building and operating well supplies, helped in the development of the plans.

SPRINGFIELD.

In the fourteen years since the Springfield Little River System was put in service the water business in Springfield has almost doubled. The output has not increased in quite that ratio because in the beginning the system was only partially metered, and during the early years with metering there was an actual reduction in output.

Springfield has grown more rapidly and continuously than any other city in Massachusetts. In addition, the policy has been followed of supplying water to neighboring communities at wholesale.

The underlying thought in doing this was that it would cost these communities at least twice as much to get corresponding service for themselves as it would cost the city of Springfield to supply them.

It would be fair to divide this advantage equally. With this done a price could be fixed that would yield Springfield a profit of 50 per cent. on all the business done, and the towns would still be getting water 25 per cent. cheaper than they could otherwise get it. These figures are not precise but they illustrate clearly the controlling thought in the business.

If the cost of the service is estimated, taking into account all the costs that there are, including interest and depreciation, and basing the rate on the actual output rather than on the rated capacity, and 50 per cent. is added, the estimate of the fair price for these takers is reached. No water-supply system will suffer by taking additional business that carries a 50 per cent. profit.

This general policy has been followed and has resulted in substantial additions to the drafts and to the required capacity.

A water-works system consists of many parts and these parts do not all come to the limit of their capacity at exactly the same time. This is fortunate for it permits the additions to be built in installments spread over a term of years.

In this case, the Little River run-off has turned out to be greater than expected; and as the storage was originally provided on a liberal scale, the source will safely carry something over 15 mil. gal. originally assumed as the capacity of the first installment. With complete development about three times this quantity will be obtained.

The pipe lines, built of lock-bar steel, coated with specially selected and prepared coal tar, will carry more water than was estimated in advance for riveted steel pipe of their present age and will therefore serve a few years longer.

The filters need enlarging first. The water, which, in dry times, is mainly drawn from the Borden Brook Reservoir on a tributary is rather

more difficult to treat than was anticipated before the works were built. There has been a much larger load of organic matter in it to be removed, and this has made chemical treatment necessary. Coagulation has been employed, and the load upon the filters has been correspondingly greater.

Notwithstanding the greater load upon the purification works, the present plant has turned out water of the highest quality uninterruptedly for the whole period of its use, and the operating costs, notwithstanding some bothersome conditions, have been on a moderate scale that has been seldom reached in water purification plants in this country.

The present plant consists of a coagulating basin holding 40 mil. gal., and three acres of covered sand filters, and the present rate of output is frequently in excess of the 15 mil. gal. per day, for which the plant was built.

Doubling the capacity of the filter plant is thus the first logical step in enlarging the plant, and this is now being undertaken.

In doing this the equipment for applying and mixing the coagulant with the water will be improved. Baffles are to be built in the very large coagulating basin which was fortunately a part of the original plant and the sand filters are to be duplicated.

Before deciding to duplicate the present plant, several alternate arrangements were considered. Among these may be mentioned placing scrubbers in advance of the sand filters to lighten the load upon them. This will not be done because present and prospective operating costs are so moderate that it would never be possible to save from them amounts to compensate for the cost of the scrubbers. With the local water and with the chemical treatment that has been employed and that has been found satisfactory, it is not thought that satisfactory purification of the water after treatment by mechanical filters would be possible. If such filters were used a continuous and heavier dose of coagulant would be essential and the operating cost correspondingly increased.

The present plant has produced water of the highest quality and with a low operating cost, and it was not apparent that any more advantageous arrangements could be made in extending it.

It is also taken into account that in the near future a very large storage reservoir will be built upon the main stream and that, with the storage of the whole supply in this reservoir, a considerable improvement in average quality of water entering the plant may be expected.

The ten-year average color of the water entering the plant is 38. This will be reduced to a much lower amount after the large proposed Cobble Mountain reservoir is in use. Fifteen years ago, before the plant was built, it was assumed that when Cobble Mountain reservoir was built and complete storage obtained, that no further use of coagulant would be necessary. With present ideas with regard to color and color removal, this view must be modified, but it still appears probable that the plant

with sand filters of full efficiency may be operated without coagulant for a considerable and increasing proportion of the time in the future.

Mr. E. E. Lochridge is Chief Engineer of the Springfield Water Works and has supervision of the construction.

PROVIDENCE.

A general description of the Providence work has already been presented by the Chief Engineer, Frank E. Winsor, Vol. 36, p. 323. What I shall say relates only to the filters which are proposed.

The water will be obtained from a storage reservoir that will be large in size and the water before filtering is expected to be of good quality. On the other hand the color records of the last seven years have indicated a distinctly higher color of the river water as it flows than was anticipated in the earlier studies. Allowing for such decolorization in the storage reservoir as is to be expected it appears probable that there will be color above allowable limits in the reservoir water for periods, the length and frequency of which cannot be closely estimated. The filters must therefore be capable of dealing adequately with considerable amounts of color as well as with the tastes and odors and other impurities to be expected in a reservoir water. The color to be dealt with on present evidence will be considerably higher at Providence than at Springfield.

The question of whether to use sand or mechanical filters has been studied at considerable length. The higher color of the raw water was one important element in the decision to use mechanical filters; another was the unusual difficulty of the site. Several sites for sand filters were studied. The material in each case consisted of sand of various grades filled with boulders, some of them weighing many tons. Excavating such material and bringing it to a uniform foundation grade and making the bottom water tight presented unusual difficulties and put an added burden on the construction of sand filters.

The water is unusually soft and it was felt that the use of mechanical filters with only a relatively short coagulation period would be likely to result in red water troubles, to the corrosion of the iron and lead service pipes, and to supplementary precipitation of hydrate of alumina in the distribution and service pipes.

The best means of avoiding these conditions at present available seems to be to use a very large coagulating basin capacity. The chemists have been working for many years on some means of accelerating the reactions, but thus far practical experience supports the idea that a large basin is the most efficient means of securing a reasonably stable and quiet water.

A valley has been found where such a basin could be constructed in connection with the Providence filters. This will hold more than a day's

supply at the ultimate rate possible from this source and several days' supply at the rates of early years. The adopted plan therefore is to give the water chemical treatment followed by passage through a very large coagulating basin thoroughly baffled, thence passing to mechanical filters.

In the design of the mechanical filters, there will be a number of novel features to adapt them to the conditions to be anticipated in this case.

Preliminary studies have been made for types of filters, combining as far as possible the advantages of both sand filters and mechanical filters, but some of these ideas may require further development before they can be safely applied in so large a plant.

Aëration of the water both before and after filtration is proposed to reduce tastes and odors and also to remove carbonic acid and thus to make the water less active in the pipes.

The Providence water now supplied has been somewhat active. Corrosion of lead pipes and fear of lead poisoning have been much discussed. Lime has been used to reduce this tendency for several years. This phase of the matter is most important and every effort will be made to turn out a water from the new works that is satisfactory in all respects and that is reasonably quiet in the pipes.

The construction of the new filters will be in charge of Mr. Winsor and his assistants.

Poughkeepsie and Albany.

I am now going slightly beyond the boundaries of New England to say a few words about plants of interest, operating under very different conditions. Poughkeepsie and Albany both take water from the highly polluted Hudson River, and it must be most carefully filtered to remove its disease-producing qualities. This is an entirely different problem from those presented in the plants previously mentioned. In both cases, gravity supplies are possible, and will no doubt be ultimately used, but in the meantime, the filter plants must be kept up to standard.

The Hudson River is so highly polluted that it is questionable whether single filtration of any type is capable of producing water meeting present exacting standards with a proper factor of safety. At any rate double filtration has been used at both of these plants for some years, and is now regarded as a necessary part of the procedure.

The water first receives chemical treatment, then goes through coagulating basins and passes to scrubbers, which are mechanical filters with only a little of the equipment omitted, and then passes to sand filters. The sand filters in each case represent the earlier plant and the scrubbers are more recent additions.

At Poughkeepsie the scrubbers were added as a war measure when increased capacity was urgently needed and when the old sand filters were having trouble in maintaining service. Since they have been used, it has only been necessary to clean the sand filters about once a year. The

scrubbers do the heavy end of the work and the sand filters finish it and remove whatever materials come through the scrubbers, including tastes and odors and at times a certain amount of hydrate of alumina. The water is aërated once only between the two sets of filters.

The Poughkeepsie plant is ample in capacity at every point for present output and has worked easily with the production of water of such uniformly good quality that the residents of Poughkeepsie are not interested at present in changing the source of supply.

During the present year a new 5-mil.-gal. covered reservoir is being built to give 20 lb. needed additional pressure and to permit water to be delivered in the city of the same excellent quality as that leaving the filters.

The old open reservoir in which objectionable algæ growths sometimes took place will be held as an emergency reserve to be connected with the system only in case of conflagration. A new loop of 24-in. pipe extending all the way from the source of supply around the business district of the city to the new reservoir has been provided and with a few main feeders will give ample distributing capacity for years to come.

At Albany, a somewhat similar general filtering arrangement was installed earlier, and has for years made operation possible, but can be improved.

One of the undesirable conditions has been that the water was pumped from the coagulating basin to the scrubbers. This has broken up the floc and has made efficient operation impossible. The filter sand in the scrubbers was too coarse and had become very dirty. The scrubbers were demoralized; floc passed entirely through them, and passing the sand filters clogged them rapidly until they could not be adequately cleaned, and it has been thought necessary to by-pass some of the partially treated water to the city.

Chlorine treatment has saved, or nearly saved, the situation from a hygienic standpoint, but the results have not been satisfactory in other respects.

It is proposed to reconstruct the scrubbers, bringing them back to standard condition; to build a new covered coagulating basin at higher level so that the water will flow from it to the scrubbers by gravity, slowly and without agitation, and to use the present coagulating basin as an intermediate receiving basin between the two sets of filters. Other changes will be needed, and when these are carried out, it is hoped that operating conditions may be brought fully up to the highest standard and maintained as long as the present source of supply is used.

It is to be noted that tests during the recent period of very low flow in the Hudson River have shown at Albany a much heavier load of fresh putrescible organic matter from sewage in the water, than has been found at Poughkeepsie and the water is correspondingly more difficult to treat at such times.

It is thought at Albany that even though a gravity supply, for which there are excellent opportunities, should be introduced in a few years, the need of better water was so urgent that the present filter plant should be put in order in any event.

Mr. F. A. Raven is Commissioner of Public Works at Albany, and Mr. Thomas F. Lawlor, Superintendent of Public Works at Poughkeepsie.

This, I believe, completes a very brief description of some of the new works under way that may be of interest.

Discussion.

Mr. J. M. Diven.* It might be interesting to know that the Poughkeepsie plant was, I believe, the original filtration plant in the United States.

Mr. M. N. Baker.† I might supplement that last remark by giving a little additional information. The late James P. Kirkwood, who was sent to Europe to investigate filtration in 1866 by the city of St. Louis, and who recommended slow sand filters for St. Louis, did not have the opportunity to build such a plant there. Mr. Kirkwood was fifty years ahead of the times, so far as St. Louis was concerned, for that city relied upon sedimentation until 1915, when it put in operation the mechanical filtration plant which many of you know about. In view of the muddy character of the St. Louis water supply, it was probably fortunate that the city did not build slow sand filters. But Poughkeepsie, New York, with the comparatively clear waters of the Hudson River as its supply, did reap the advantage of what Mr. Kirkwood learned about slow sand filtration in Europe, and particularly in England, and built a slow sand filtration plant in 1870, with Mr. Kirkwood as engineer. In 1874–75, Hudson, N. Y., also built slow sand filters, with J. B. G. Rand and J. H. Enigh as engineers. It may be added that Mr. Kirkwood's report on his studies of water treatment abroad was published in book form in 1869, with the title, "The Purification of River Waters." So far as I know, this was for many years the only book on water purification available in the English, if indeed in any language.

Mr. J. Frederick Jackson.‡ I would like to ask Mr. Pirnie if he thinks that there is any probability of their resorting to the very novel feature which was proposed when this plant was under design, of flooding the surface of the ground over the wells in order to increase the supply? I believe the plant has been in continuous operation in pumping, and as the records indicate, there has not yet been any necessity of resorting to that.

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* Secretary, American Water Works Association.

† Associate Editor, *Engineering News-Record*.

‡ Director, Bureau of Engineering, State Department of Health, Connecticut.

MR. PIRNIE. Experience during the past dry season indicates that sufficient water for the present can be pumped from the wells without resorting to artificial methods of increasing the ground water supply. The depth of porous material in this valley is fairly shallow. This gave reason for doubt as to whether or not there would be sufficient cross-sectional area of flow to supply the wells when the ground water level was depressed by continued pumping.

Two methods of increasing the amount of ground water in the immediate vicinity of the wells were therefore outlined. One was that mentioned of flooding the surface of the ground about the wells, and the other was the construction of a shallow canal in the sandy material paralleling the wells with provisions for cleaning the sand at intervals. Both the flooding of the ground and the canal would be supplied from the streams in the valley. Experience so far with the supply indicates that it will not be necessary to resort to either of these measures at present. They may be carried out, however, if they are found to be necessary when larger quantities of water are required in the future.

MR. W. L. HATCH.* I want to say, in regard to the plant at New Britain, that we have been operating at our full capacity of 3 mil. a day throughout the summer, more as a test of what could be done and making sure that everything would run all right, than from actual necessity, as we have our main reservoir nearly full at present. We are now operating at 1-mil. capacity, having one 8-hr. force a day, simply taking care of our high service reservoir, which cannot be operated from our main plant. During the five weeks that it was operated in July and thereabouts at 24-hr. service the water maintained its level, after dropping down some 5 or 6 ft. That is, the ground water, after going down 5 or 6 ft., remained at that level through the entire time, and since it is being run one-third of the time the water is somewhat higher in the ground. We see no evidence whatever that we will not have an ample supply, as this has been the driest season we have had in a great many years in our vicinity.

* Chairman, Board of Water Commissioners, New Britain, Conn.

THE SELECTION OF PUMPING EQUIPMENT FROM THE STANDPOINT OF STATION ECONOMY.

BY FRANK A. MAZZUR.*

[*Read September 19, 1923.*]

In preparing this paper on the selection of pumping equipment, I had in mind the problem that comes up sooner or later before every water-works manager, in the selection of a pumping unit on account of the increased demand for water, or from existing equipment having become used up or obsolete.

Up to a few years ago this question would have been confined to simply the capacity and type of a steam-driven unit but developments in recent years have made it necessary to make a study of the possibilities of purchased electric power, and oil engines as well as the usual steam-driven pumps.

The two points of paramount importance are dependability and operating costs, and in a pumping plant furnishing the water supply for a community, dependability is by far the greater of these two points. In making the comparisons of the various types of apparatus I have based the figures on units of about 3 000 000-gal. capacity in twenty-four hrs., as the majority of pumping plants in New England are of this size or smaller.

The crank and fly-wheel pumping engine is without question the most economical in the use of steam, a unit of this size being able to deliver about 124 000 000 ft. lb. per 1 000 lb. of steam under the ordinary steam conditions found in existing pumping stations. They also have an excellent record for dependability and low cost of upkeep. Their price, however, is high compared to other types of pumping equipment, but even with its high cost this type of steam-driven pump is a favorite where the maximum steam economy is the main consideration. However, a great many installations of pumping equipment are made for stand-by service or peak-load conditions, and as an addition to an existing plant consisting of buildings, boiler equipment, etc.

In making our comparisons we are considering only a plant having good boiler equipment, etc., and it is an additional installation of this kind that we are taking up in this paper, and not the building of a new plant where no previous investment has to be taken into account.

A good many of the installations put in during the past few years have been made where the existing equipment has been of sufficient or nearly sufficient capacity but of obsolete type. Let us consider a plant equipped

* Mechanical Engineer, Boston, Mass.

with two direct-acting compound pumps, one of which is to be replaced with a pump of somewhat greater capacity. As the direct-acting pumps even when new, have a very poor duty compared with what we look for at the present time, the new unit would naturally be of a different type. In the event of the available space being able to accommodate a crank and fly-wheel engine without any great alterations in the building, this type of engine should undoubtedly receive serious consideration.

However, it may be that to install a crank and fly-wheel pumping engine would entail an extensive addition to the building the cost of which added to the high cost of the pumping engine would bring the fixed charges on the investment up to a point where the total yearly cost would be greater than if a unit of different type and poorer duty, but of much lower cost were installed.

Turbine Drive.

The turbine-driven centrifugal pump has the advantage of low first cost and very small space requirements compared with the crank and fly-wheel pumping engine. The duty, however, is by no means as good, but as mentioned above this is very often more than offset by its lower cost. I mentioned previously a duty of about 124 000 000 ft. lb. per 1 000 lb. of steam for the crank and fly-wheel engine. Under the same steam conditions a duty of about 100 000 000 ft. lb. can be obtained with the turbine-driven centrifugal pump. Before making the actual detailed comparison I would like to point out some of the advantages of this type of unit. In addition to the small space requirements a very small foundation is needed. The unit is practically self contained, and the arrangements of suction and discharge pipes can be worked out in a very simple and inexpensive manner.

Now let us assume that instead of replacing an obsolete unit with one designed for every-day service at best economy, we have the case of a plant equipped with an economical pumping engine for regular service, and a stand-by unit which is either too small in capacity for the increasing demand, or is worn out or obsolete. In this case a steam turbine-driven centrifugal pump offers the best solution of the problem, for the space requirements of this pump and its appurtenances are such as to require no more room than is occupied by a direct-acting duplex pump of considerably less capacity. Moreover, the price is as low as any dependable pumping equipment and the economy is such that if operated for long periods, the operating costs would not be so very much above that of the most economical type of steam-driven pump that they might have in for their main unit.

Electric Drive.

In the foregoing descriptions of pumping apparatus steam drive only has been considered and in many cases there is no reason to consider any other source of power. Where the boiler plant and all of the steam machinery is in good condition it is very difficult to show where a saving can be

made by reverting to electric drive, especially in a plant of such size as to require only one man on duty. This one man will be required in any event and while perhaps a small saving may be effected from the fact that in operating an electrical unit a licensed engineer is not required, it is always necessary to have an intelligent man in charge.

In the way of electrically-driven apparatus there are two types of pumps that are usually considered. These are the plunger pump geared to an electric motor and the centrifugal pump direct connected to the driving motor.

The comparison of these two types of pump is very similar to the comparison of the crank and fly-wheel pumping engine and the turbine-driven centrifugal. The horizontal plunger pump of 3 000 000-gal. capacity would practically be the same pumping unit that would be driven by the crank and fly-wheel engine, and the direct-connected centrifugal pump would be the same pump as the one driven by the geared steam turbine. As in the case of the steam drive it is simply a question of fixed charges and operating costs. The guaranteed pump efficiency of the horizontal plunger-type pump of this size is about 90 per cent. and the efficiency of the centrifugal pump about 80 per cent., and in the tabulation of operating costs which we will come to later these two types of electrically-driven pumps run surprisingly close together in fixed charges and the cost of electric current.

Oil Engine Drive.

The methods of driving the steam and electrically-driven pumps considered so far are very familiar to all of us, but there is another form of drive that is making headway in pumping engine service, and the economy of this form of drive is bringing it rapidly to the front.

The oil engine of the Diesel type has been known for quite a number of years and up to the time of the war had been used with considerable success in many forms of industry. It did not receive much consideration in installations for water supply, as dependability could not be sacrificed for economy. During the war great advances were made in the design of Diesel-type oil engines and to-day they may be classed as prime movers which have demonstrated their value from both the standpoints of economy and dependability, and it is my opinion that the time has arrived for water-works engineers to give the oil engines serious consideration if they are going to operate their plants at the highest possible economy.

Water-works installations have for many years held the record for high efficiency, the results obtained in large pumping plants being far and above any performance that could be hoped for in plants developing power for industry, the nature of pumping service being such as to render this high efficiency possible. Surprising as it may seem an oil engine-driven unit consisting of a Diesel oil engine geared to a horizontal plunger pump, of the size that we are considering, can give a duty far greater than the

largest and most refined type of steam-driven pumping unit that has ever been built. For instance let us take the duty ordinarily obtained on a cross-compound pumping engine of 3 000 000-gal. capacity; this is as mentioned previously 124 000 000 ft. lb. per 1 000 lb. of steam. An oil-engine-driven unit of this same size can operate on a cost for oil that would be equivalent to a duty of at least 225 000 000 ft. lb. per 1 000 lb. of steam.

In the case of the steam engine the economy of a plant will vary greatly in accordance with its size. With the oil engine, however, the

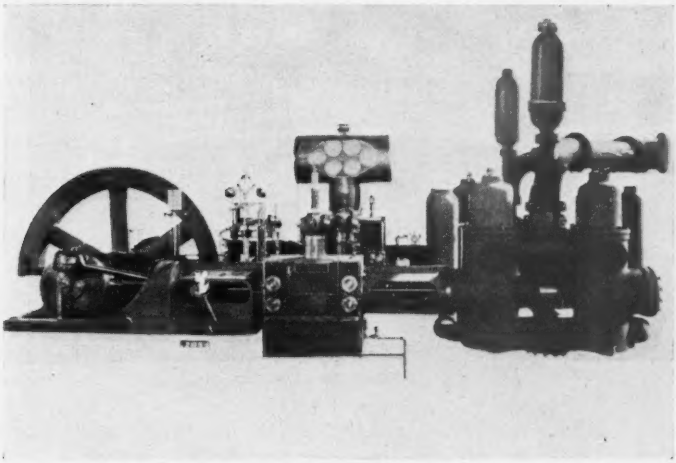

FIG. 1. CRANK AND FLY-WHEEL PUMPING ENGINE.

efficiency of comparatively small units is almost as good as the units of very large size, and this feature is making it a very attractive proposition for water-works pumping installations of small and medium sizes.

To familiarize our minds with the various types of pumping units we are discussing, a few illustrations will no doubt be of assistance.

FIGURE 1.

This illustration shows a pumping engine of 3 000 000-gal. capacity and is no doubt familiar to you all as it is very universally used in modern high-grade pumping service. This unit is provided with Corliss valve gear and is of the type and size of a unit recently installed by the Webster Water Works of Webster, Mass., and is the unit from which we obtained the costs and performance included in the tabulation to be shown later and which you may remember we have mentioned as 124 000 000 ft. lb. per 1 000 lb. of steam.

FIGURE 2.

This shows the turbine-driven centrifugal pump in use at the High Service Pumping Station of the Brookline Water Works. This particular unit is of 4 000 000-gal. capacity and you can judge of the amount of space taken by the size of windows and other fittings in the engine room. The

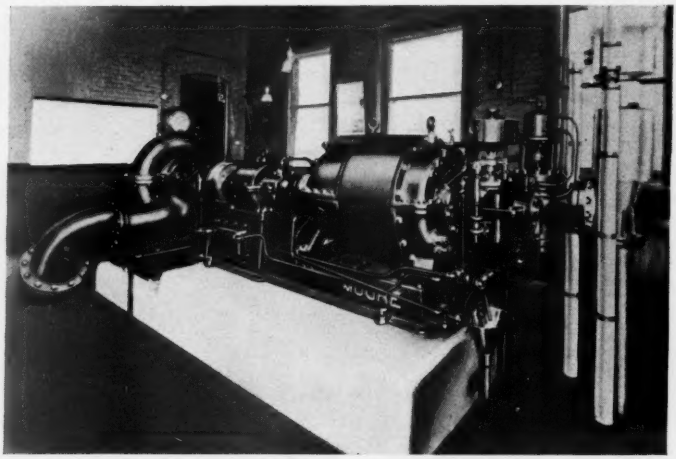

FIG. 2. TURBINE DRIVEN CENTRIFUGAL PUMP.

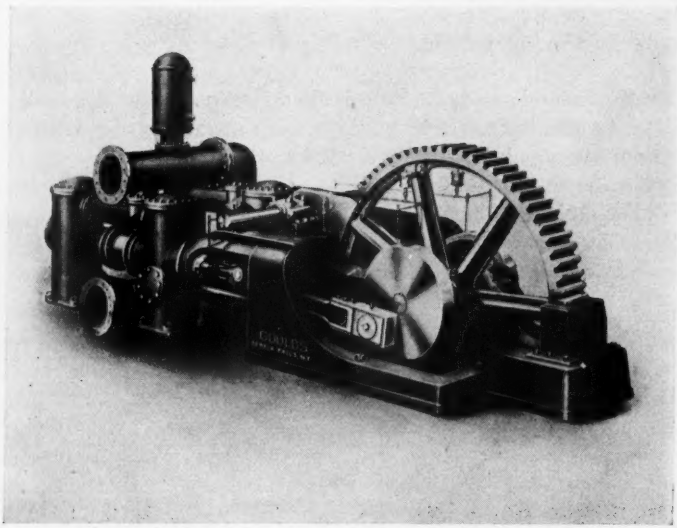

FIG. 3. HORIZONTAL PLUNGER PUMP FOR MOTOR DRIVE.

condenser and air pump are located in the basement adjacent to the foundation. The speed of the pump is about 1 600 r.p.m., and this is accommodated to the turbine speed of approximately 4 500 r.p.m. by means of the Herringbone reduction gears interposed between the two. A unit of this size and type is capable of delivering from 95 000 000 to 100 000 000 ft. lb. of energy, per 1 000 lb. of steam under average conditions found in existing plants.

FIGURE 3.

This figure shows a horizontal plunger pump, the pump end itself being practically the same as the crank and fly-wheel steam-driven pump illustrated in the first figure. This pump, however, is provided with a large gear for operation by means of an electric motor. In smaller sizes the motor-driven geared pump is usually of the vertical triplex pump.

FIGURE 4.

Here we have the direct-connected centrifugal pump. This has the lowest first cost and requires a smaller space than any type of pump that

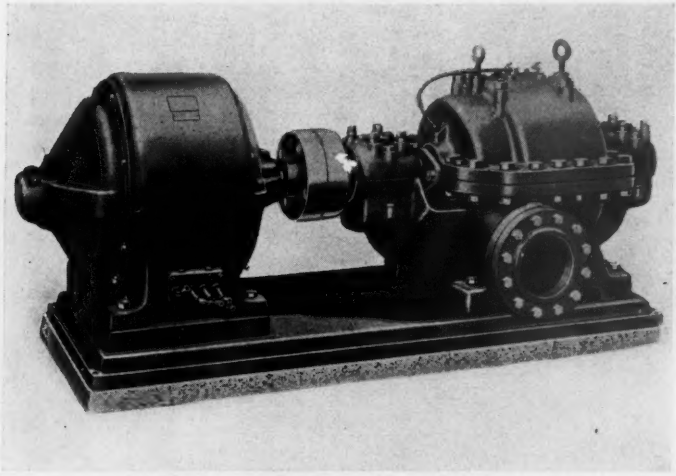

FIG. 4. MOTOR DRIVEN CENTRIFUGAL PUMP.

can be considered for a pumping installation, but it is also the lowest in pumping efficiency. In many cases, however, the low first cost and small amount of attendance required may justify its use where electric current can be obtained at a very low price.

In considering the installation of electrically-driven apparatus it is very important to consider the possibility of interruption of service. Some

of you will doubtless remember the interruptions due to the sleet storm about two years ago, and wherever there is a possibility of an interruption of this nature it is advisable to provide an additional drive for the electrically-driven pump with either an oil or gasoline engine. In the case of the centrifugal pump this is very easily accomplished as the shaft can be provided with a coupling at each end, one coupling to be connected to the motor and the other to the oil or gasoline engine. When operating on the motor the coupling bolts are removed from the engine coupling which remains idle.

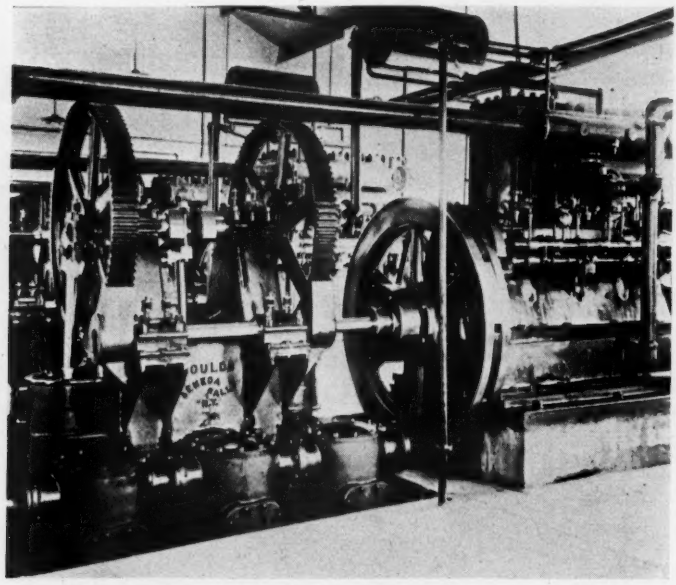

FIG. 5. VERTICAL TRIPLEX PUMP DRIVEN BY OIL ENGINE.

FIGURE 5.

We now come to the oil-engine-driven units. This illustration shows a triplex pump of a capacity considerably smaller than what we are considering in this paper but of interest as a type.

FIGURE 6.

This shows another type of oil-engine drive for a geared pump, this being about the same capacity as the previous figure. The engine in this case is a single-cylinder Diesel.

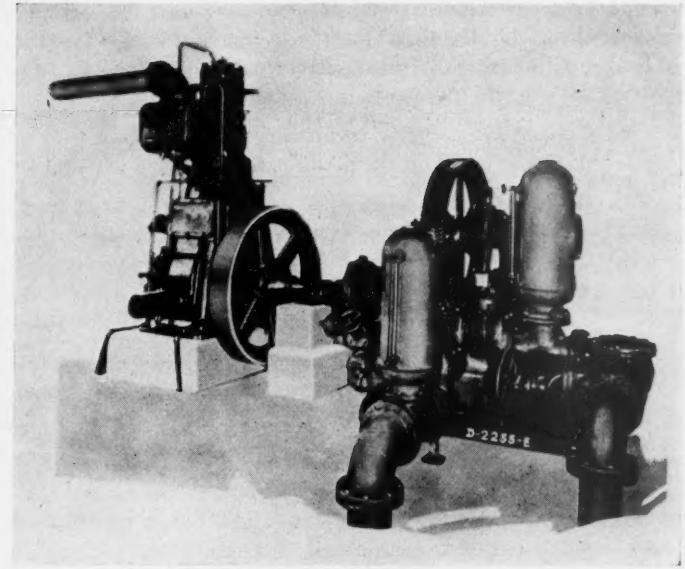

FIG. 6. VERTICAL TRIPLEX PUMP DRIVEN BY SINGLE CYLINDER DIESEL TYPE OIL ENGINE.

FIGURE 7.

This next and last illustration of pumping equipment shows a horizontal plunger pump of about 3 000 000-gal. capacity geared to a 2-cylinder Diesel engine. This particular unit was installed in the water works of New Britain, Conn., about a year ago, and in the tabulation of comparative

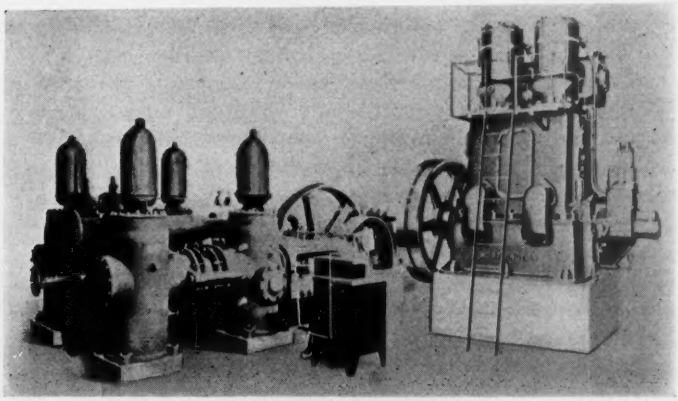

FIG. 7. HORIZONTAL PLUNGER PUMP DRIVEN BY TWO CYLINDER DIESEL TYPE OIL ENGINE.

costs which I have referred to several times I have used the cost and performance data of this installation. The amount of space taken up is probably slightly in excess of a steam-driven unit of the same size.

In the March meeting of the Water Works Association Dr. Charles E. Lucke read a paper on oil-engine performance supplemented by a paper read by H. M. Chase based on the performance of either this or a similar unit.

COMPARISON OF OPERATION COSTS OF VARIOUS TYPES OF PUMPING EQUIPMENT.
CAPACITY 3 MILLION GALLONS IN 24 HOURS.
INSTALLED AS ADDITION TO EXISTING STEAM PLANT.

	Steam Driven.		Electrically Driven.		Oil Engine. Driven.
	Crank and Fly-Wheel Plunger Pump.	Turbine-Driven Centriufgal Pump.	Horizontal Plunger Pump.	Centrifugal Pump.	Horizontal Plunger Pump.
Cost of unit installed with appurtenances and necessary change to building..	$33 000	$15 000	$17 500	$10 000	$31 000
On Basis of Pumping Eight Hours Per Day.					
Interest and depreciation..	$3 960	$2 250	$2 530	$1 500	$4 650
Cost of fuel or current.....	2 660	3 480	6 170	6 870	1 450
Cost of banking fires for 16 hours.....	820	820	.....	.....	.....
Cost of coal for heating...	.....	.....	200	200	100
	$7 440	$6 550	$8 900	$8 570	$6 200
On Basis of Pumping Sixteen Hours Per Day.					
Interest and depreciation..	$3 960	$2 250	$2 530	$1 500	$4 650
Cost of fuel or current....	5 330	6 950	11 010	12 100	2 900
Cost of banking fires for 8 hours.....	410	410	.....	.....	.....
Cost of coal for heating...	.....	.....	200	200	100
	$9 700	$9 610	$13 740	$13 800	$7 650
On Basis of Pumping Twenty-Four Hours Per Day.					
Interest and depreciation..	$3 960	$2 250	$2 530	$1 500	$4 650
Cost of fuel or current....	7 990	10 400	15 700	17 250	4 350
Cost of banking fires.....	.....	.....	.....	.....	.....
Cost of coal for heating...	.....	.....	200	200	.....
	$11 950	$12 650	$18 430	$18 950	$9 000

In order to select the pumping equipment for any particular installation there are many things to be considered and several angles from which

the proposition may be viewed, and in the tabulation here shown I have eliminated all items of operating cost that would be practically the same no matter what type of unit might be installed.

As a multiplicity of figures will sometimes obscure the salient points and dwarf their importance, in this tabulation I have taken only the fixed charges consisting of interest and depreciation and the cost of fuel or current. The interest and depreciation on the crank and fly-wheel pumping engine I have taken at 12 per cent., whereas on all of the other types this has been taken at 15 per cent. The cost of coal I have taken at $8.50 per ton. The cost of current I have based on the charges as made by the Boston Edison Company for the current consumption required for an installation of this size, and this figures out as listed below:

2.00 cents per k.w.h. on the basis of an eight-hour day.
1.70 cents on the basis of a sixteen-hour day.
1.64 cents on the basis of a twenty-four-hour pumping day.

In some localities adjacent to a large water power, current may be obtained at somewhat lower rates, but I think that on the whole, current will cost more rather than less than the figures here given. In figuring the steam consumption and the oil consumption I have based the calculations on the guarantees as made by the manufacturers.

I wish to repeat here that we are considering only an installation as an addition to an existing plant. An entirely new installation would be a different matter and while the principles involved would be the same I have not tried to cover the question of a new installation in this paper.

One of the important factors in considering a problem of this kind is the number of hours a day the plant is to be operated. With a large reservoir capacity eight hours pumping will usually suffice. With an ample standpipe and a small demand at night many stations operate with two shifts totalling sixteen or eighteen hours. Other plants pumping against direct pressure have to operate a full twenty-four-hour day.

Now let us consider the first case in this tabulation, a plant operated eight hours per day running at the rate of 3 mil. gal. in twenty-four hours, or 2 088 gal. a minute. The first column shows a crank and fly-wheel pumping engine with interest and depreciation, fuel for pumping and fuel for banking fires sixteen hours per day, making a total of these three items of $7 440 per year. The next in line is the turbine-driven pump with a total of $6 550 per year. The electrically-operated units figure $8 900 yearly cost for the plunger type against $8 570 for the centrifugal. The oil engine shows the lowest yearly cost, this being $6 200. On the basis of the eight-hour day any one of these types could be selected with good reason. Referring to the steam drive, while the turbine-driven pump shows a lower operating cost, the Water Board might decide that with the money available in their treasury they would be justified in purchasing

the highest grade equipment with an assured long life at high efficiency. If on the other hand it would be necessary for them to borrow money to finance the larger expenditure they would undoubtedly purchase the steam turbine-driven outfit. With the operating costs shown for either of the electrical units they would scarcely be justified in installing either of these unless their boiler plant happened to be in such poor condition that the entire replacement of this part of the station would be required in a short time. There is very little choice between the plunger pump and the centrifugal pump from the standpoint of operating costs, and the probability is that with the lower investment and the lower operating costs the centrifugal pump would be selected instead of the higher-priced plunger pump, if electric drive should be decided upon.

The oil engine shows a yearly operating cost of $6 200 as against $6 550 for the turbine-driven centrifugal, and with the steam plant in good condition and the operating force thoroughly trained in handling steam machinery it would not seem advisable to change to oil for the slight difference in operating cost shown.

The next tabulation or the sixteen-hour day shows quite a change in conditions. The fixed charges remain the same but the cost of fuel brings the most efficient apparatus strongly forward. With the slight difference between the crank and fly-wheel pumping engine and the turbine-driven centrifugal pump there is no doubt that the crank and fly-wheel would be chosen as the greater value on account of the lower fuel consumption, and the probability that this type of pump would still be in service twenty or more years after installation, if its capacity should be sufficient for the increased demand, and as the growth of the community is always considered in determining the size of unit, a selection would undoubtedly be made of sufficient capacity for quite a number of years in advance.

On the sixteen-hour day the two types of electrical unit are again of about equal operating cost, but these costs are so far above steam operation as to put them out of the running unless current can be obtained at an extremely low price.

In the sixteen-hour day the oil engine shows to much greater advantage and a saving of $2 000 per year in operating costs is something that cannot be ignored. There is always a resistance against making a radical change, and unless a good reason can be found for change it is undoubtedly wise to tread the known and beaten path in a matter as important as the water supply for a community. However, the path of dependability has already been beaten in marine service where oil-engine-operated vessels make long voyages without a single shut down of their engines. They have amply proven their merit.

The twenty-four-hour day shows a still greater advantage for the crank and fly-wheel pumping engine in a steam-operated plant and clearly demonstrates the inadvisability of purchased electric power for operating

under these conditions. The oil engine shows very close to $3 000 difference in operating cost and from the standpoint of station economy is clearly the best choice in this latter comparison.

In gathering the data and making up this tabulation I have tried as far as possible to use figures that I knew to be correct both as to installation costs and operating expenses. The crank and fly-wheel pumping engine, the turbine-driven pump and the electrically-driven centrifugal pump are based on the costs of installations actually put in. Similar installations made in other plants would probably vary somewhat from the figures given, and all of these costs therefore are to be taken as approximate. The chief value of a tabulation of this kind is to bring out the salient points and emphasize the extreme care with which the problem should be approached. Each and every installation is a problem by itself, and unless viewed from every angle, and every factor carefully weighed it is very easy to make a selection that will be disappointing in the results obtained. Before making a selection it is always advisable to have the problem thoroughly analyzed by an engineer versed in all the phases of the situation.

Mistakes in engineering are usually costly and it is only by careful diagnosis that these may be avoided and satisfactory results assured.

Discussion.

Mr. Caleb M. Saville.* I would like to ask Mr. Mazzur if the same relative differences that he has shown in his tabulations, which I understand were for a three-million-gallon plant, would hold for one of less capacity and one of greater capacity, that is, in a general way.

Mr. Mazzur. In a general way, yes. There would be a change, especially in the electrical. As the consumption of current goes down the rate goes up. You will notice that for the 8-hr. day it was 2 cents per k.w.h.; for the 16-hr. day, 1.7; for the 24-hr. day, 1.64. Up to 20 k.w.h. the Boston Edison Company has a flat charge of $2 for the service; then a certain number of k.w.h. — I think it is 1 000 or 2 000 — at 3 cents; then another space for 2 cents, all of which will amount to 10 000 k.w.h.; and after that it is at the flat rate of 1 cent. So that if you use a large amount of current you get the benefit of the 1 cent rate above 10 000 k.w.h. per month. The smaller the unit the more it will cost per k.w.h.

Mr. Saville. My question was a little more as to the efficiency of the engines themselves.

Mr. Mazzur. They will go down somewhat. In the case of the oil engine, they will not go down so very much.

Mr. Saville. Would they go down in the same relative proportions, each to the others; or in the smaller capacity would one of the plants be more efficient than the other?

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*Chief Engineer, Board of Water Commissioners, Hartford, Conn.

MR. MAZZUR. I think in the small plant you would find that the economy would go down in steam-driven units faster than it would in electrically-driven units. In the oil engine it would be very nearly flat; there would not be very much change. The oil engine goes down very slowly. In other words, the oil engine in the smaller capacity is very nearly as efficient as in the larger sizes.

MR. J. M. DIVEN.* Wouldn't the 10-mil. or 20-mil. direct-acting steam engine show better economy than the small one? In other words, wouldn't you get up to something like 200 mil. ft. lb.?

MR. MAZZUR. In the large steam engines you get over 200, to perhaps 210 — I know they have reached 203 and 205, as against 124 mil. in the small size. That would be going into triple expansion engines.

MR. FRANCIS T. KEMBLE.† Around Boston do they make any difference in regard to the charge for certain hours of electric current? Do they require them to be off the line while the peak is on? And the peak load is generally around six o'clock in the evening. Do they penalize them?

MR. MAZZUR. I do not know of that.

MR. KEMBLE. That makes some difference in electrical operation.

MR. MAZZUR. If they do make a change, I do not know it. It might be in a special contract. But the rates as published and given out for prospective purchasers of current, as I have seen them, do not take that in.

MR. HENRY A. SYMONDS.‡ I want to express my appreciation of the splendid paper that we have listened to. Mr. Mazzur has brought out most clearly the special features of the comparison between the different types of drive for moderate-size pumping plants.

The question of steam, oil or electricity comes up in practically every installation. Unless a very careful study is made of the merits of the different cases, the electric drive is apt to have a decided advantage because it takes up small space, it has a low first cost, it apparently can be operated without much supervision, it comes the nearest to being foolproof of any type which can be installed, it requires for ordinary operation no highly experienced man; but a more careful study of the cases frequently shows up certain defects in the first reasoning.

For instance, if you compare the oil engine with the electric drive on the basis of no attendance for the electric drive and full attendance with a high-class man for the oil engine, you make a very favorable case for the electric drive. But here again the practical working out is not according to the theory that is advanced. You will find that more or less attendance is given the electric drive; in fact, in most plants of a size to take care of a moderate-size water works it is thought best to keep some one there at all times while the machine is operating. There are exceptions to that, but that is the common rule. In fact, the actual cost of attendance usually

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* Secretary, American Water Works Association.
† Secretary, New Rochelle, N. Y., Water Company.
‡ Consulting Engineer, Boston, Mass.

does run very nearly the same on the electrically-driven plant as it does on the oil-driven. That may not be as it should be; in fact, I do not think it is. I believe we should operate more with non-attendance than we are doing.

Regarding operating costs, I can't add anything to what Mr. Mazzur has said. There is such a difference between the cost of any ordinary operation by electricity and that of oil that, while the attractive features of the electric drive — the low first cost, small space required for the pumping station, and ease of operation — appeal very strongly, if a careful study is made, it is evident in nine cases out of ten that the oil engine is ahead in economy.

In an installation which has been made within the last month, there was a strong prejudice in favor of using one oil-engine drive for the principal work and a stand-by with electric drive, and the design was completed with that in view, but we found in that particular locality the current was uncertain. Some of the mills were out of power at times when they were depending on electricity, and prejudice existed against having to depend at any time on electric power with this defect, so the plant was redesigned and two oil engines installed.

Now, of course, as the first cost of the oil engine is much greater than the motor, depreciation and interest become much greater items. The close comparison by Mr. Mazzur between the different types of pumps brought out that particular feature. There is a marked difference in the efficiency between the centrifugal pump and the vertical triplex, but in some of the cases the difference was actually more than lost because of depreciation and interest.

I should say here that one important thing is to have, in operating an oil engine, a fairly competent man. In different plants that have come to my attention, some of which have been under my direction for a time, it appeared that the life of those engines was just about in proportion to the capacity of the men operating them. There are some engines that we have run for fifteen years under skillful, competent, economical men that seem to be as good as the day when they were put in. Others that we have not run as long have largely gone to pieces because of the less efficient maintenance. Depreciation does cut a great figure, and becomes much greater with the oil engines.

But the fact is that in analyzing every feature that enters into the determination of what power shall be used, you can install the present Diesel or semi-Diesel — I should say the semi-Diesel is more suited to the smaller plants in some cases than the true Diesel, although there has been a wonderful advance in getting out the true Diesel at a moderate price — allow the heavier depreciation and interest charges, and full attendance, as against the lower depreciation, lower interest charge and eliminate entirely the attendance on the electrical units, and in the average case the oil engine will still come out decidedly ahead.

MR. J. M. DIVEN. The speaker fully agrees with the last speaker on the nonattendance question. No machinery can be trusted to entirely take care of itself. Some years ago the speaker had an experience with an electric-driven triplex pump, pumping from a well. The pump was located about two miles from the power house and the only attention it had was by a man who went there once a day to oil and examine the outfit. Pumping was at intervals to a reservoir. One day after the power had been turned on it was found that no water was being pumped and a trip to the pump house revealed a mass of scrap iron, a completely ruined pump. Just what happened was never found out, whether the sudden start caused the motor and pump to race or whether the pump failed to take suction owing to low water in the well will never be known.

MR. KEMBLE. I should like to ask as regards the oil engine, when you try to run at capacity for any length of time, how it stands up. In steam units you run 75 to 80 per cent., and if forced to run at full capacity for any extended time at all you find your runner making all sorts of noises. Have you had anything of that kind?

MR. MAZZUR. I do not believe I am as competent to answer that question as Mr. Hatch of New Britain. If Mr. Hatch is here, I think he can tell us.

MR. W. L. HATCH.* I think this installation was completed in the spring, and after the completion it was run at capacity, 3 mil. a day for thirty days, with only one shut-down, which was only for a few minutes, during that time. The card indicator showed that it was running up to 3 mil. I think the contract figure was approximately 2 900 000. It ran over that: between 2 900 000 and 3 000 000 all of that time. Since that time it has been in operation eight hours out of twenty-four at the rate of 3 mil. gal., and is still running, and we have had absolutely no trouble, no shut-down for any engine trouble during the summer. The actual cost figures are approximately one cent per 100 cu. ft. of water pumped, against about a 360-ft. head. The first figures showed slightly under the rating, and after the pump had been running for two or three weeks it went over the rating, so that it is running now at slightly over the rated amount.

MR. F. H. HAYES.† It has given me great pleasure to listen to the paper of Mr. Mazzur.

Possibly I might say something about the dependability of oil engines. At Scituate some years ago there were two oil engines put in, and on a hill there was a standpipe. It became a question of when to start the engine and not overflow the standpipe. They experimented in this way. They fixed a tank on the wall and put oil in it. By observing the height of the water in the standpipe they were able to determine the quantity of oil necessary to be supplied to the engine in order to fill the standpipe. When the tank was emptied the engine stopped. An attendant went there only at night and morning. That, I think, was twenty years ago.

* Chairman, Board of Water Commissioners, New Britain, Conn.
† Of Hayes Pump and Machinery Company, Boston, Mass.

I am glad to hear what Mr. Mazzur has said in regard to the oil engine, for the reason that I have tried to interest so many in it.

The real point of why you should put in an oil engine instead of a steam engine or steam turbine is because of the low cost of operation. There is no other way of pumping water for so little money as by the use of oil engines. These are, as we all know, semi-Diesel engines. There have been great improvements in the semi-Diesel engine. I personally have used most all of the oil engines. I have used the Hornsby-Akroyd, the Otto, Fairbanks-Morse, Crescent, Meitz & Weiss, and now we are using some of the Bessemer engines.

But when you get into the matter of the upkeep of oil engines, I think that Mr. Mazzur has gone a little far in saying it is 15 per cent., if I correctly understood him, when he compares the oil engine.

MR. MAZZUR. That is what I figured.

MR. HAYES. From our experience with them, we do not get any repairs for them, except once in a while. Once in a while there is a bad one that comes out from the shop, but you can't help that. But when you come to compare them all the way through their upkeep is less even than the steam engine, and I am very glad to know that they are coming to the front.

MR. FRANK A. MARSTON.* Answering a question, I know of one instance in which a problem was taken up with the Edison Electric Illuminating Company of Boston and they indicated a willingness, on a unit perhaps of such size as we have been talking about this afternoon, to make a favorable special rate in case the pump was run during certain hours, as I remember it, in the early morning. I know of other large electric companies in this vicinity who have submitted similar offers to make special rates not covered by their schedules, where the pumping would be done at a time that would be of benefit to them.

Another thought has come to me in connection with stand-by service, which was furnished in connection with an inquiry made in the city of Springfield this year. The power company indicated a willingness to put electric motors in a pumping station without subjecting the user to a stand-by charge provided there was no other form of power in the station, but if electric motors were to be put in in addition to a Diesel engine or a steam engine, in other words, be a stand-by source of power, then a servic charge would be levied which would involve prohibitive expense.

I would like to mention a hypothetical case and ask Mr. Mazzur's judgment as to the effect on the efficiency of the prime movers. Assume you had a 3-mil.-gal. pumping unit, but operating at a rate of 800 000 gal. per day on the average and with a maximum rate of 3 mil. gal. per day for fire service. What would be the relative efficiencies of the several types of prime movers referred to?

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* Of Metcalf & Eddy, Boston, Mass.

MR. MAZZUR. The oil engine would not be as good under those conditions for horse power delivered. To work it out on a question of fixed charges and operating costs would be rather difficult now for mental arithmetic. But I can say that under a varying load the steam engine will come nearer its guaranteed economy than the oil engine will — probably much nearer on a wide range of variation.

MR. MARSTON. Where would the steam turbine come? I assume that the electrical equipment would not be economical under those conditions.

MR. MAZZUR. The steam turbine would not be as good as the crank and fly-wheel engine. It can be regulated, but of course we know that when you cut down on the speed of a turbine you commence to lose in efficiency very rapidly.

MR. HAYES. We have had occasion to answer some questions in reference to the use of oil as compared with electricity, and for your information I will say that it has worked out this way: taking oil at 10 cents a gal., you will have to obtain your electric power for less than a half a cent per k.w.h. We have proved that a great many times.

MR. A. PRESCOTT FOLWELL.* I saw about a week or two ago some figures sent out by the Federal Government that were compiled up to within a few weeks, I think, showing figures for the past four years for plants generating electricity. Of course this is not exactly water works, but along that same line. The power generated by electric plants during the four years — 1919 to 1923 inclusive — had increased 12 per cent. in the case of those using coal and 52 per cent. for those using oil, showing a much more rapid increase in the use of oil than in coal during the last four years.

MR. E. P. HOWARD.† Our company builds, of course, all of the various types of machinery which have been talked about here tonight. In regard to this question of repairs and maintenance, and things of that kind, while Mr. Mazzur did not directly mention it, I think that he included the figure for repairs and maintenance in his depreciation on each one of the units, so that it was taken care of.

Now, he also probably — at least I think he did — took it at what he thought was a fair average. We do know that there are plants of all of these various types that run for years and years and nothing happens; we do know, also, that perhaps in some other places something does happen. We do know that perhaps in a plant that has run for several years without anything happening, they may have a breakdown which will amount to quite a considerable item in any one element. So that the only fair way to get at it is to take a fair average over the entire field, which I think Mr. Mazzur has done. And I want to say here that I do not think I have ever heard a fairer explanation and comparison of the different types than he has made here to-night.

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* Editor, *Public Works*.

† Of Worthington Pump and Machinery Corporation.

In regard to the different types of engines on a variable load, we have a number of cases here in New England where there is a system with a standpipe in it and perhaps a limited storage in the standpipe. Perhaps you have not got enough water in your standpipe to carry you through a heavy fire. Perhaps you have not got enough to carry you through 24 hr. without pumping. There you have to start up in the morning and pump at a fixed rate until the standpipe is full, and then perhaps slow down for the remainder of the day and operate at reduced capacity until you get ready to shut down at night and leave a sufficient amount of water in the standpipe to carry you through until the next day. Now, for those variable conditions we have found that there is nothing that quite equals the crank and fly-wheel machine over that variation, because it keeps nearer to its maximum efficiency. The oil engine can be made to pretty nearly approach that, because it can have its speed varied without any very great change in its economy. But it does change somewhat. But probably next to the fly-wheel engine it keeps the closest to its maximum efficiency.

I do not know that there is anything in particular that I have to say more, except, on the electric end in a great many cases, there are some things that come up after you have got the electric power in, that make your bills larger than you thought they were going to be before you started in, unless you are fortunate enough to make a contract similar to what the president did in his case, where he limited the electric company to a fixed sum, which should not be exceeded, for pumping a certain amount of water.

MR. CHARLES W. SHERMAN.* In a comparison between the 8-hr., 16-hr. and 24-hr.-per-day operation, Mr. Mazzur has used the same figure for fixed charges covering interest and depreciation, and, as Mr. Howard seems to understand it, of ordinary repairs. It seems to me that a plant that is run 24 hr. a day will necessarily have to meet more costs for repairs in the term of its life than one running 8 hr. a day, and there is an item there that will have some effect. It may be too slight to have any bearing on this question.

MR. MAZZUR. I think that the figure I took for interest, depreciation and ordinary repairs was large enough to cover the 24-hr. service. I think the general consensus of opinion here is that I have been too high on those figures.

MR. SHERMAN. It would be less than that on an 8-hr. service?

MR. MAZZUR. Yes, it would.

PRESIDENT SANDERS. There is one feature of comparison of costs of running a 3-mil.-gal. pump by steam and then changing to electricity, that I am not sure has been considered in your paper. With steam you would have to have an engineer and a fireman while with electricity only one man would be required. That would make some difference in the

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comparison between steam and electricity figuring on an 8-hr. day. Were your figures made on that basis, Mr. Mazzur?

MR. MAZZUR. I believe I mentioned in the paper that both of the 3-mil.-gal. plants had one man on duty for each shift. I do not think that many plants of greater capacity than 3 mil. get along with one man, but I do know of several plants of that capacity where just one man does the firing, the wheeling of the coal and the oiling of the engine. In other words, it is a one-man plant. And if it is a 16-hr. day, then two are employed — that is, one man per shift. If it is a 24-hr. day, three men, or one man at a time. And in a way I selected that particular limit of size as being one on which you could make the compairson without figuring labor at all.

MR. KEMBLE. As regards the having but one man on the plant I might call to your attention that this is a matter that has been given pretty thorough consideration and that, in many instances, operating men have decided that they did not want theirs to be a one-man plant. A single man may have a spasm or something happen to him. Again a single man may wander away from his plant and leave it to take care of itself.

Of course on a small plant, the runner and the fireman may have but little to do and have much time on their hands.

MR. MAZZUR. The plant I mentioned in the paper, in which I used the crank and fly-wheel pumping engine, is the Webster Water Works, and with the crank and fly-wheel pumping engine they are using about 1 000 or 1 100 lb. of coal a day, and that is not a very big day's shovelling for a man. Previous to that they were using a duplex pump and he was shovelling just about twice the amount of coal, and he still looked healthy. So that I do not believe that they intend to add to the force now. I think there are more plants of that size running with one man than there are with two on duty.

MR. HOWARD. If I might add one more word, which I forgot, in regard to the cost of the oil-engine fuel. One gentleman spoke about the cost of fuel having gone up so much in the past few years. These costs which were put on the sheets by Mr. Mazzur were on the basis of present-day cost of oil, and if oil only cost half or two thirds as much a few years ago you see how the comparison was then. Even at the present cost of oil you have seen how the comparison is. Of course those costs are also based on the latest up-to-date Diesel engine, which has a higher first cost, more money invested, but which has a lower average consumption to offset it.

THE COVERING OF OPEN SERVICE RESERVOIRS IN WHICH FILTERED OR GROUND WATERS ARE STORED.

BY GEORGE C. BUNKER* AND AUGUST G. NOLTE.†

[*Read September 19, 1923.*]

In the past many open service reservoirs have been constructed due to one of the following reasons:

(1) To a lack of knowledge of the changes which will take place in stored ground or filtered waters;

(2) To the necessity of building and placing in service a storage basin of any kind in the shortest possible time in order to effect an improvement in the sanitary conditions of a community suffering from the lack of a water supply;

(3) To the use of the reservoirs for storing unfiltered water until they were required later on for the storage of filtered water.

In recent years a diminishing number of open service reservoirs for the storage of ground and filtered waters have been built as the public has become more interested in the protection of its water supplies and in many instances has reached the conclusion that if it is necessary to purify the latter it is fully as necessary to keep them in the same condition of purity prior to consumption. However, a few open service reservoirs are still constructed through reasons of false economy, through the blindness of amateur engineers to certain well known facts concerning the storage of water, or through their failure to include a roof as an integral part of a reservoir instead of submitting two estimates of cost, one with a roof and the other without a roof. The latter procedure is certain to start an argument by one or more of the parties to whom the proposition goes for approval because a chance is presented to reduce the first cost of the reservoir and thereby effect an apparent saving. This leads to the necessity of demonstrating that the present apparent saving will develop into a future expenditure of the same amount with about 50 per cent. more added to it to pay for an experiment which has been tried many times without success in other communities.

In general the covering of an open service reservoir, once built, is harder to accomplish than it is to obtain the additional money for the cover before the construction of the reservoir is started, assuming of course that filtered or ground water is to be stored in it. We know of no better illustration of the difficulty of covering an existing open service reservoir

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than the struggles of Edward E. Wall, Water Commissioner of St. Louis, Mo., to obtain an appropriation for covering the open service reservoirs at Baden and Bissell's Point, the latter of which were built about 1870 as sedimentation basins. Attention is called to the following illuminating remarks from his annual report for 1920:[1]

"As an example of how needed improvements that could and should have been done at least five years ago, will now cost almost twice as much, the covering of the filtered water storage basins at Baden and Bissell's Point may be cited.

"Every year beginning with 1915 an ordinance has been drawn appropriating money for this work; every year the Board of Public Service has approved the proposition and recommended the bill to the Board of Aldermen for passage; with equal regularity, each year, the bill is never allowed to reach the stage where it can be voted upon.

"This work was not postponed from year to year because of the lack of available funds, but because laymen have opposed their judgment against that of trained and experienced engineers, and decided that the basins did not need covering.

"It has been said that politics is the only profession in which the amateur presumes to enter the lists on equal terms with the professional, but here we have a case where those who can not qualify even as amateurs, pass upon a highly technical question with more of assurance than is assumed by the expert.

"As pointed out in the Chemist's report, page 58, the Bissell's Point basins exposed the filtered water to contamination from the dirt and filth blowing from the stock trains passing over the Merchants Bridge, and from the flying refuse of the public dump just south of Ferry Street.

"That they should have been left uncovered so long is a reproach against the City's regard for cleanliness, but a continuation of this indifference will constitute more than a reproach, it will become a positive disgrace."

Unfortunately politicians do not have a monopoly in passing judgment upon "a highly technical question" for not infrequently amateur, inexperienced, or narrow-minded engineers are offenders in this respect with the result that more attention is paid to their opinions, backed up by their profession or by their position, simply because they are occupying positions of greater authority, than to those of men ranking as experts in the purification of water. Then again some engineers with minds too narrow to take into consideration the broader aspects of the subject will not consider any question of this sort except from the standpoint of dollars and cents.

The conditions leading up to the covering of a low-service reservoir on the Canal Zone and the resulting improvement may be of some assistance to those who are working to obtain covers for reservoirs or to those who contemplate the construction of new reservoirs. The water supply for the Pacific end of the Canal Zone is obtained from the Chagres River, the largest stream discharging into Gatun Lake. From the intake it is pumped through 11 miles of cast-iron pipe to the Miraflores Purification Plant where it is aërated, clarified with aluminum sulphate, filtered, and disinfected.

After disinfection with liquid chlorine the greater part of the water flows by gravity for a distance of four miles to a pumping station at Balboa. In this station there are two high-service and three low-service pumps so

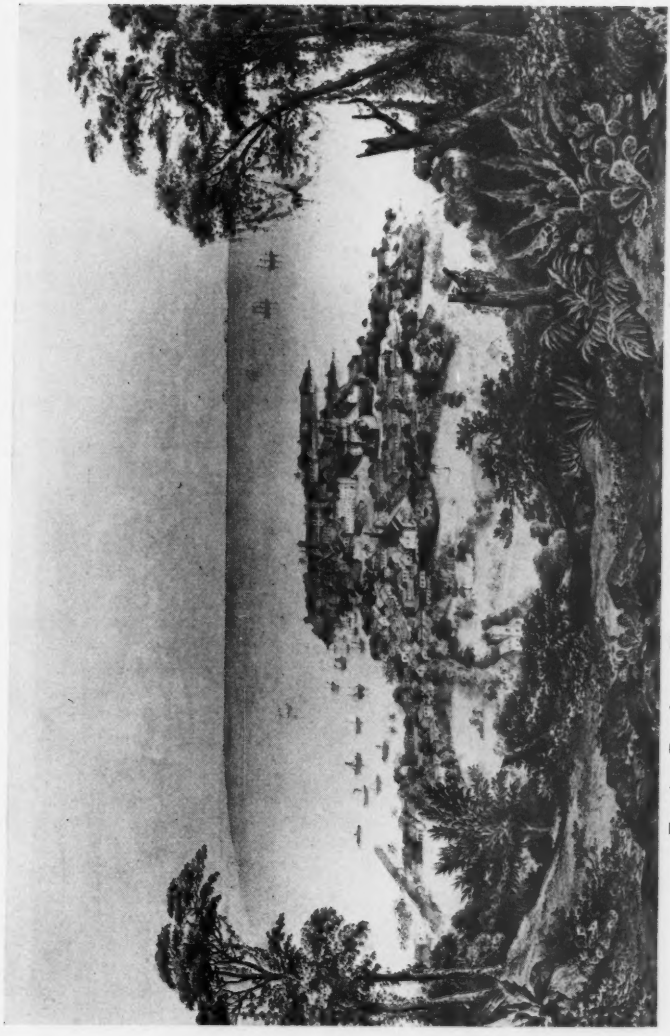


FIG. 1 — BIRD'S-EYE VIEW OF CITY OF PANAMA FROM ANCON HILL, 1855.

FIG. 2. — HIGH SERVICE RESERVOIR CONSTRUCTED IN 1909.

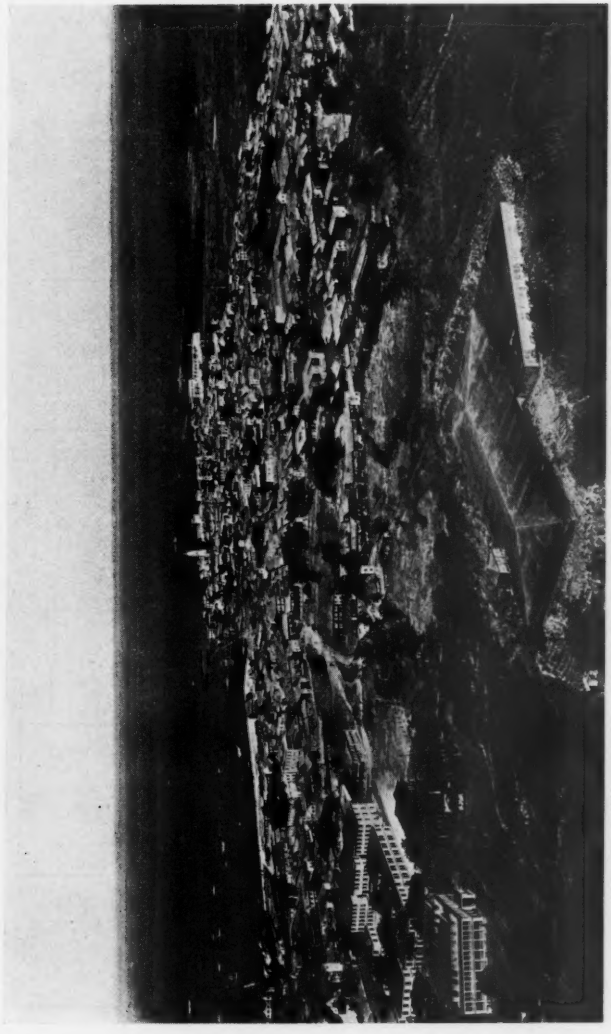
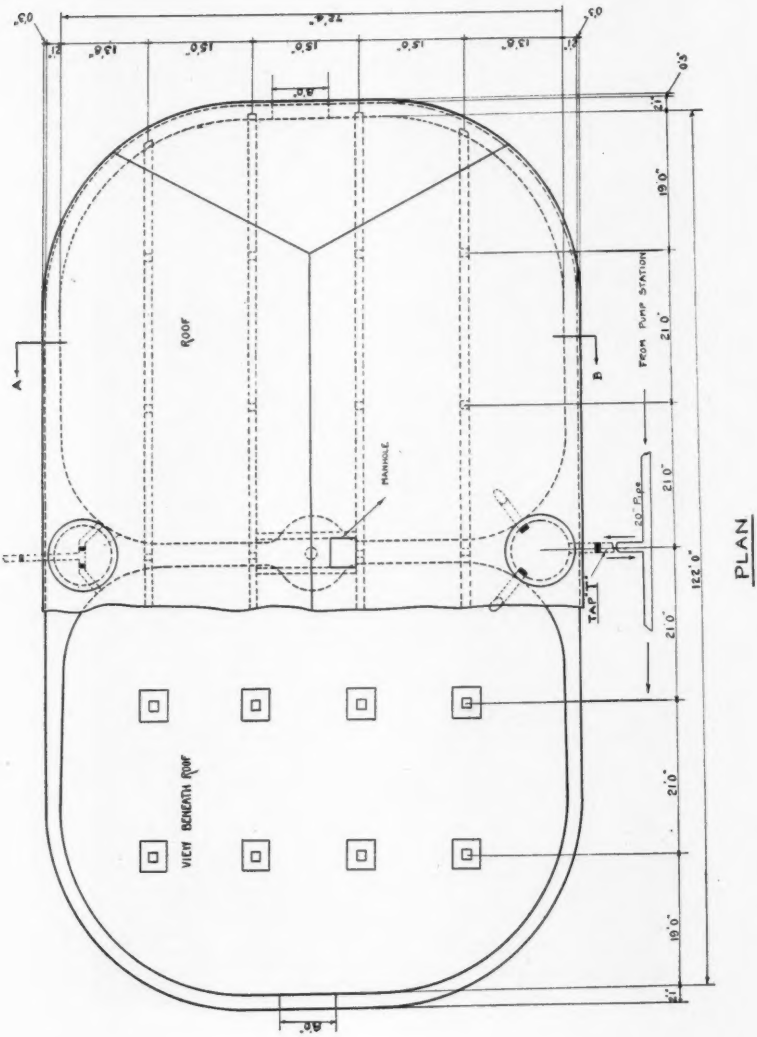


FIG. 3. — HIGH SERVICE RESERVOIR WITH ADDITION AND ROOF CONSTRUCTED IN 1914.


ROOF
MANHOLE
FROM PUMP STATION
TAP
VIEW BENEATH ROOF
A
B
122'0"
19'0"
21'0"
21'0"
21'0"
21'0"
19'0"

PLAN

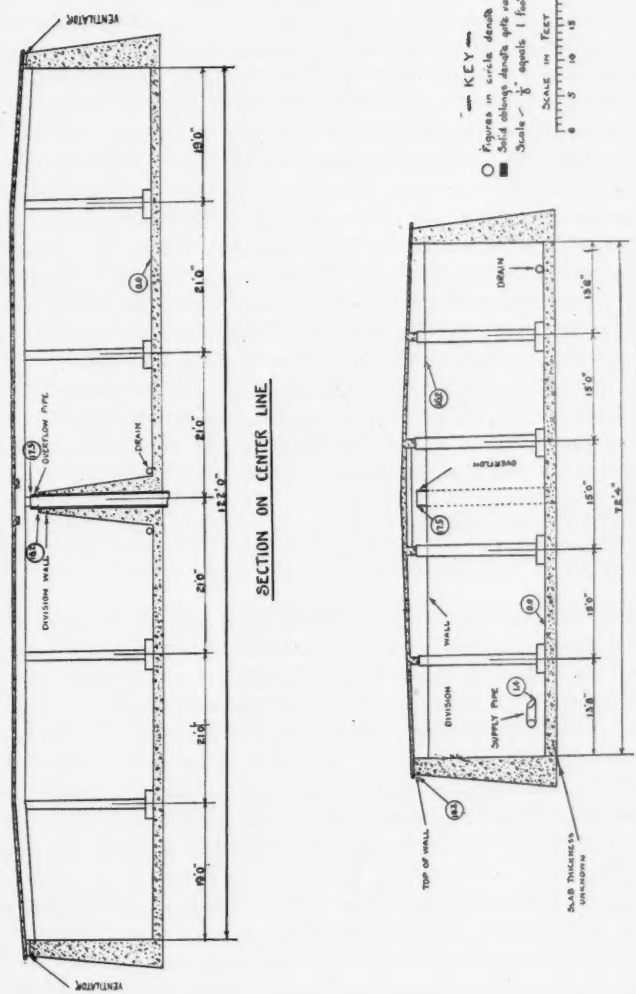


FIG. 4.—DETAILS OF LOW SERVICE RESERVOIR.

interconnected that any one of the five may be used for pumping water into any part of the distribution system. Connected to the distribution system there are two concrete reservoirs or surge tanks; one, the high-service reservoir, the other, the low-service reservoir.

During the fiscal year ended June 30, 1909, an uncovered, reinforced concrete high-service reservoir,[2] 120 by 125 ft. in plan by 13 ft. deep, with a capacity of 1 000 000 gal., was built on the side of Ancon Hill at a point such that the elevation of the floor was 283.5 ft. above sea level. Its cost was $32 573. Prior to this time an elevated tank, 50 000 gal. capacity, furnished water to the Ancon Hospital grounds but increased consumption rendered it inadequate for the service demanded of it. On June 1, 1914, a reinforced concrete addition[3] to this reservoir was completed and placed in service, increasing the storage capacity by 1 500 000 gal., thus making the total capacity 2 500 000 gal. The addition was built in an irregular shape on account of the topography and in plan measured 110 ft. in width and from 127 ft. to 186 ft. 5 in. in length. At the same time a roof was placed over the combined reservoirs. From this reservoir filtered and disinfected water is now supplied to those sections lying at greater elevations than can be served from the low service reservoir.

The low-service reservoir[4] was placed in service November 1, 1905, as part of the system of water works installed by the Americans to improve the sanitary conditions in the city of Panama. In connection with the construction of this reservoir the following comment by Davis[5] is of interest:

> "Its construction was delayed in favor of more important matters until the dry season of 1905 came on; and during that season every drop of water in the vicinity was needed for Ancon Hospital and none was available for concrete."

The reservoir was set on top of a knoll on one side of the Canal Zone community known as Ancon, the elevation of the floor being 119.1 ft. above sea level, sufficiently high for supplying the city of Panama and the lower parts of Ancon and Balboa with a normal water pressure of 35 lbs. per sq. in. It is oval in shape, 122 ft. long by 72 ft. 4 in. wide, inside measurements, by 19 ft. 2 in. deep. It was constructed of concrete and the lower half of the structure was backed up by earth. A division wall, 16 ft. $2\frac{1}{2}$ in. high, along its short axis, divides the reservoir into two sections of equal size. At one end of the division wall there is a well into which the water discharges from the pipe line from the pump station, and from which it may be diverted into either section through a short length of pipe, 20 in. in diameter, the flow line of which is 16 in. above the floor. When water is flowing out from the reservoir it passes from each section through the same pipes into this well and thence into the distribution system.

In the center of the reservoir, running down through the division wall, there is a 16-in. overflow pipe, the top of which sets at such an elevation as to give a maximum depth of 17 ft. $6\frac{1}{2}$ in. of water or a capacity of 500 000

gal. in each section. At the other end of the division wall there is another well serving as a valve box for the valves on the 6-in. waste pipes which connect to a single drain pipe.

From October, 1913, up to the completion of the Miraflores Purification Plant in March, 1915, the low-service reservoir was supplied with water from Miraflores Lake filtered through pressure filters in Ancon. The supply taken from this lake contained, off and on, large numbers of diatoms. From time to time the filter runs would be shortened to such an extent by these diatoms that sufficient water could not be filtered to keep the reservoirs full and to furnish sufficient wash water. Relief for short periods was obtained by applying copper sulphate to the arm of Miraflores Lake from which the supply was taken. As a result considerable numbers of diatoms were present in the filtered water delivered into the reservoir so that in 10 samples of this water collected between September 3, 1914 and January 21, 1915, the total organisms varied from 11 to 390 and the amorphous matter from 10 to 400 standard units per c.c. After the filtered water from the Miraflores Plant was discharged into the reservoir the organisms decreased gradually in numbers so that during November and December, 1915, the examinations yielded counts not exceeding 14 standard units per c.c. Up to October, 1918, routine microscopic examinations were made of samples of water from both the low-service (uncovered) and the high-service (covered) reservoirs. At that time, due to pressure of other work and changes made necessary by the War, these examinations were stopped and have never been resumed as a matter of routine work. The following table gives a comparison of the numbers of organisms in the two reservoirs:

TABLE NO. 1.

MICROSCOPIC ORGANISMS IN SAMPLES OF WATER FROM THE LOW AND HIGH SERVICE RESERVOIRS IN ANCON, C. Z.

Total Organisms in Standard Units Per C.C., 1 500 C.C. of Water Concentrated.

Year.	Low-Service Reservoir, Uncovered.					High-Service Reservoir, Covered.				
	Maximum.	Minimum.	No. of Samples examined	Samples containing no organisms.		Maximum.	Minimum.	No. of Samples examined	Samples containing no organisms.	
				No.	Per cent.				No.	Per cent.
1916	124	0	61	21	34	24	0	53	25	47
1917	24	0	75	68	91	4	0	46	39	85
1918	39	0	40	20	50	3	0	40	38	95

From this table it is seen that the largest number of organisms were found in the uncovered reservoir and that a larger percentage of the samples from the covered reservoir were free from organisms, *i.e.*, none were found in the concentrates from 1 500 c.c. of water, which of course does not mean that there were none in the entire body of water.

During several years daily samples of water have been collected from taps in buildings in Ancon and in the city of Panama in order to determine if the proper amount of liquid chlorine was being added to the filtered water leaving the Purification Plant. During the fiscal years ended June 30, 1918, 1919, and 1920 the colonies of bacteria averaged less than 50 per c.c.,* the actual figures as published in the annual reports being as follows:

Year Ended June 30.	Colonies of Bacteria Per c.c. 24 Hours at 37.5° C.	B. Coli Index Per Liter.
1918†	24.1	23.0
1919	46.4	12.1
1920	15.4	7.9

Occasionally a count greater than 100 per c.c. was obtained from one of the taps but in some cases it was found that water was dripping over the outside of the faucet, thereby contaminating the sample, and in other cases it was considered that the collector of the sample had contaminated it as the counts from the same tap on previous days had been running low and no change had been made in the application of the chlorine. Furthermore the counts from the samples collected on the same day from other taps on the distribution system were low which was considered as confirming the theory that the sample yielding the high count had been contaminated. All of the sampling points were located on service pipes tapped into mains through which there was a constant circulation of water so that the influence of dead ends was eliminated. Later on we came to the conclusion that the sporadic high counts were due to other causes than contamination by the collector as we will point out in another part of this paper.

Starting in June, 1920, several high counts of over 100 bacteria per c.c. were obtained from taps on the distribution system supplied by the low-service reservoir and members of the Colon group were isolated from 14 out of 300 portions, 10 c.c. each, of 60 samples of water. Hitherto members of the Colon group had not been isolated from more than 5 out of 300 portions, 10 c.c. each, of 60 samples of water. In July, members of the Colon group were isolated from 21 out of 285 portions, 10 c.c. each, of 57 samples of water. In August there was about the same percentage isolation of members of the Colon group but a greater number of samples contained more than 100 bacteria per c.c., while in September and October several samples of water from the same taps yielded counts of 200 to 1 200 bacteria per c.c.

Table No. 2 shows the bacteriological characteristics of samples of water collected from the distribution system during five months prior to the covering of the reservoir.

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* All counts of bacteria given in this paper were determined on nutrient agar after 24 hours incubation at 37.5° C.

† First year during which liquid chlorine was used in place of hypochlorite of lime.

TABLE NO. 2.

SUMMARY OF THE BACTERIOLOGICAL CHARACTERISTICS OF THE SAMPLES OF WATER COLLECTED FROM TAPS ON THE DISTRIBUTION SYSTEM DURING THE MONTHS OF JUNE TO OCTOBER, INCLUSIVE, 1920.

Month.	Colonies of Bacteria Per C.C. on Nutrient Agar. 24 Hours at 37.5° C.				Members of the Colon Group.			
	No. of Samples.	Average.	Maximum.	Per Cent. of Samples Yielding Sterile Plates.	No. of Samples.	10 C.C. Portions.*		
						No. Tested.	No. Negative.	Per Cent. Negative.
1920								
June	59	22	150	6.8	60	300	286	95.3
July	57	36	170	8.8	57	285	264	92.6
August	61	59	275	1.6	61	305	287	94.1
September	60	85	800	6.7	60	300	295	98.3
October	93	70	1 200	10.7	62	310	307	99.0

TABLE NO. 3.

SUMMARY OF THE BACTERIOLOGICAL CHARACTERISTICS OF THE SAMPLES OF WATER COLLECTED FROM TAPS ON THE DISTRIBUTION SYSTEM DURING THE MONTHS OF NOVEMBER 1921 TO MARCH, 1922, INCLUSIVE.

Month.	Colonies of Bacteria per C.C. on Nutrient Agar. 24 Hours at 37.5° C.				Members of the Colon Group.			
	No. of Samples.	Average.	Maximum.	Per Cent. of Samples Yielding Sterile Plates.	No. of Samples.	10 C.C. Portions.*		
						No. Tested.	No. Negative.	Per Cent. Negative.
1921								
November	65	6	65	20.0	39	195	195	100.0
December	77	4	43	22.1	46	230	230	100.0
1922								
January	69	1	7	42.0	38	190	190	100.0
February	69	5	55	23.2	53	265	265	100.0
March	67	9	55	13.4	67	332	329	99.1

The puzzling part of the problem was that on one day a high count was obtained from one sample and low counts from the other samples; on another day the counts from all the samples were high; while on the preceding or following day the counts were low again. A special set of samples, was collected from various points on the distribution system in order to eliminate the factor of carelessness in the routine collection of the samples, with the result that the bacterial content of the samples varied sufficiently to indicate that some other explanation would have to be sought besides contamination during collection. In order to eliminate any influences of dirty mains or dead ends a request was made for a

* Five 10 C.C. portions of each sample are inoculated into lactose broth.

general flushing of the mains in the district supplied by the low-service reservoir. This was carried out on September 8, 1920, but high counts in some of the samples still continued intermittently. On September 13 the north half of the reservoir was cleaned and on the following day the south half was cleaned. On September 14 the counts from all the samples collected were low but at the end of four days the counts were again high. On the same days samples collected from the district supplied by the covered high-service reservoir yielded low counts.

For several days we had been convinced that conditions in the low-service reservoir itself were responsible for the high counts in the distribution system, in other words that the large numbers of bacteria found in the mains were actually present in the water before it left the reservoir. However, we were thrown off the track for a time by obtaining low counts in samples from a tap " T " (see Fig. 4) on the one main through which the water entered and left the reservoir. On studying the conditions we found that this reservoir was virtually an open standpipe with one main leading into it. When the pumpage into the distribution system exceeded the consumption, the excess water flowed into the reservoir and the level was raised. With the reverse condition existing water flowed from the reservoir into the distribution system and the level dropped. With these conditions in mind samples were collected from tap " T " at intervals of thirty minutes over a period of six hours. The counts from these samples showed that the water entering the reservoir contained only two or three colonies of bacteria per c.c. while that flowing out contained from 205 to 420 colonies per c.c.

To make certain that the water pumped into the reservoir from the Balboa pump station contained low numbers of bacteria, *i.e.*, that no multiplication occurred in the disinfected water during its flow through four miles of pipe line from the purification plant, samples were collected at the Balboa pump station over a period of six hours at intervals of thirty minutes. The colonies of bacteria ranged from 0 to 3 per c.c. These results showed conclusively that the water pumped into the reservoir from the pump station, through a 20-in. pipe line, 4 950 ft. long, contained small numbers of bacteria.

On the day following the above tests a sample of water, collected from a tap in a building close to the reservoir, while the level of the water in the latter was falling, contained 380 bacteria per c.c. A few hours later a sample collected from the same tap but with the water flowing into the reservoir contained only 5 bacteria per c.c. All of these tests indicated definitely that when the pumpage into the reservoir exceeded the consumption in the district, the mains, at least those in the close vicinity of the reservoir were filled with water containing small numbers of bacteria. On the other hand when the consumption exceeded the pumpage for several hours, the mains were filled with water from the reservoir which contained several hundred bacteria. In other words a multiplication of bacteria

was taking place in the reservoir. The daily samples in Ancon and the city of Panama were collected between 7.00 and 8.00 A.M. Between these hours the level of the water in the low-service reservoir was usually falling and consequently samples collected between these hours and within a reasonable distance from the reservoir contained larger numbers of bacteria than at some other period during the day when the water was rising in the reservoir.

During the period of August to November, 1920, chlorine was applied to the filtered water leaving the purification plant at the rate of 3.23 to 3.63 lbs. per million gal. (monthly averages) or 0.39 to 0.44 part per million of available chlorine. The majority of the samples collected from the distribution system supplied from this reservoir during this period contained no residual chlorine while the remainder contained not over 0.01 part per million. However if we had tried to stop the multiplication of bacteria by carrying an excess of residual chlorine, the consumers would have complained about the odor and taste of the water supply.

On September 27 both sections of the reservoir were again emptied, cleaned, and refilled with water from the Balboa pump station. On September 28 the counts had fallen but by October 1 they had increased again and varied from 1 300 colonies per c.c., in samples from the surface, to 1 800 colonies per c.c., in samples from the bottom.

On October 6 one side of the reservoir was emptied and the surface of the walls examined. The entire surface of the unplastered walls was badly pitted or roughened, the depressions in some places being as much as one half inch deep. All of the depressions contained a dark greenish deposit which under the microscope showed the presence of diatoms, filaments of algæ, bacteria, and amorphous matter.

In order to ascertain to what extent this deposit might contribute to the multiplication of bacteria in the water in the reservoir the following experiment was performed. Two sterile wide mouth bottles, of about 1 liter capacity, were each filled with 750 c.c. of disinfected filtered water from the main running to the Balboa pump station. Plates made from each bottle of water showed no colonies on nutrient agar after 24 hours incubation at 37.5° C. One bottle was marked " A " and the other, " B." To the water in " B " there was added 0.1542 gram of the deposit described above. To the water in " A " nothing was added.

Bottle " B " was thoroughly shaken for two minutes and a plate was then made from the water in it. At the end of 24 hours only 4 colonies of bacteria per c.c. had developed. Immediately after the above samples had been taken, both bottles, uncovered, were set outdoors. At the end of 24 hours exposure the bottles were thoroughly shaken and plates made from the water in each. Bottle " A " was found to contain 4 colonies of bacteria per c.c. while bottle " B " contained 700 colonies per c.c. Both bottles were again set outdoors for another 24 hours, at the end of which time the water in each bottle was again examined. The water in bottle

"A" contained 5 colonies of bacteria per c.c., while that in bottle "B" contained 165 000 colonies per c.c. Bottle "A" was again set outdoors for five more days, at the end of which time it was found to contain only 7 colonies of bacteria per c.c.

This experiment demonstrated:

First. That the bacteria (developing on nutrient agar at 37.5° C.) in the disinfected filtered water do not multiply when it is placed outdoors in a sterile bottle for periods of one, two, and seven days.

Second. That the deposit on the walls of the reservoir was the principal factor in the multiplication of the bacteria in the water stored in it.

It is true that the water in the reservoir was continually changing while that in bottle "B" was not changed during the experiment. However, the water in the reservoir was never completely displaced by fresh water from the pump station, the elevation in general varying each day from about 10 to 17 ft. 6 in. The 16 inches of water on the bottom below the effluent pipe would never be entirely changed under the operating conditions.

In the latter part of October, 1920, both sections of the reservoir were emptied, the walls cleaned as thoroughly as possible, and a coat of whitewash applied although we insisted that the application of the latter was useless for preventing a recurrence of the multiplication of the bacteria. During the latter part of this month the recommendation was made that the unplastered portions of the interior surface of the reservoir be plastered and that a roof be placed over it.

After the reservoir had been cleaned and whitewashed the multiplication of bacteria still continued although not to the same extent because the cleaning with wire brushes had removed a large part of the deposit from the walls. On November 10 the south section of the reservoir, filled to an elevation of 16 ft. 4 in., was treated with $9\frac{3}{4}$ lb. of copper sulphate, equivalent to a dosage of about 2.3 parts per million, and was taken out of service. On the 15th and 16th the treated water was run to waste and the walls and bottom flushed with filtered and disinfected water. On the 17th the north section was taken out of service, treated in a similar manner, and then replaced in service on the 22nd.

During the first half of January, 1921, the unplastered portions of the walls, amounting to 637 sq. yds., were plastered in order to prevent the accumulation of algæ and food material to the extent made possible by the existing rough surfaces. This step proved to be of material assistance in reducing the degree of multiplication of the bacteria in the stored water and was advisable in view of the uncertainty of covering the reservoir at a later date. The plastering, including all preparatory work, cost $1 678.95.

With a few exceptions the counts from the samples collected from the taps on the distribution system ran below 50 colonies per c.c. during the months of December, 1920, and January and February, 1921, and

no members of the Colon group were found in 1, 10, and 50 c.c. portions of the 136 samples collected.

Near the end of the latter month a vigorous growth of green filamentous algæ appeared in the reservoir. Later on the predominant organism was identified by Professor Geo. T. Moore * as Mougeotia. From this time on we experienced continuous trouble with this organism, the growth developing to such an extent that two weeks after a cleaning of the reservoir the water would contain many long strings and floating masses,

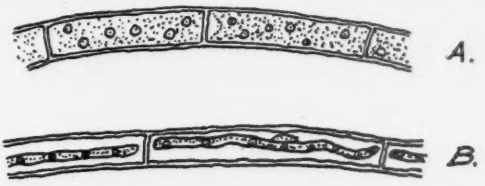

FIG. 5. — MOUGEOTIA SPECIMEN.

A. Showing the Surface of the Chlorophyll Plate. B. Showing the Edge of the Chlorophyll Plate. X About 500. (Original.) After Ward & Whipple.

necessitating repeated cleanings at intervals of three weeks or less. Masses of the growth entered the pipes of the distribution system and decomposed with the result that disagreeable odors and tastes were imparted to the water drawn from the taps in some of the houses. The progressive development of the growth of the Mougeotia after a cleaning of the reservoir was watched by collecting samples of water from each half of the reservoir and filtering a quart portion through a cotton disc furnished with the Wizard Sediment Tester.† Attention was called to this simple apparatus by Professor George C. Whipple[6] in 1914 and superintendents of water works will find it very useful for detecting growths of microscopic organisms in uncovered reservoirs. We also made frequent inspections of the reservoir to watch the development of the Mougeotia.

During the period of trouble with this organism the bacteria in the samples from the distribution system did not exceed 50 per c.c. in contrast with the high counts obtained from similar samples prior to the cleaning and plastering of the walls of the reservoir. It is evident that the cleanings of the reservoir were made frequently enough to prevent the death of the Mougeotia and an accompanying increase in bacteria. It is also evident that the frequent cleanings of the reservoir prevented the passage into the distribution system of any great amount of the Mougeotia with subsequent decomposition and an accompanying increase in bacteria. Undoubtedly if samples of water had been collected from a great many points on the distribution system some of the samples would have yielded high counts due to the Mougeotia being carried into sections of slow circulation

* Director, Missouri Botanical Garden, St. Louis, Mo.

† Creamery Package Manufacturing Company, Albany, N. Y.

and light draft with subsequent settling out on the bottom of the mains and decomposition. If the reservoir had been allowed to remain uncovered for several years longer we have no doubt that the bacterial counts would have risen because there would have been a cumulative deposition of algæ in the mains and through their decomposition a cumulative increase of food material for the bacteria.

We did not consider it advisable to treat the water with copper sulphate and keep the reservoir in service and objections were made to taking it out of service entirely so that the contents might be treated with copper sulphate and allowed to stand for a few days in order to make certain that all of the cells adhering to the walls would be killed. It was useless to treat one section at a time with copper sulphate, waste the water after standing a few days, and refill it with fresh water, because this water would have been seeded from the growth in the other section, as birds were continually skimming through the surface of the water in both sections.

Later on the funds for covering the reservoir became available and the roof over the north section, — the south section remaining in service, — was completed on August 21, 1921. The north section was then placed in service and the roof over the south section completed on October 25, 1921.

In constructing the roof over each section, eight reinforced concrete columns, 14 in. square, spaced as shown in Figure 4, were poured in place on top of concrete footings, 4 ft. square and 1 ft. thick. The supporting beams, 12 by 18 in., for the 4½-in.-reinforced-concrete slab, were poured first, followed by the slab itself before the concrete had set hard. No expansion joints were used in the roof slab, the fresh concrete of each day's work being run up against that of the previous day's work. Later on these joints or cracks were chipped out and asphalt was poured in to prevent drippings into the reservoir during rains. Run of bank gravel from the Chagres river, passed through a 2-in. mesh screen, was used in the proportion of 8 cu. ft. to 1¼ bags of Portland cement. Over the division wall the roof is supported by four short columns resting on the wall. In the center of the roof a manhole, 4 ft. square, was left and covered with a ventilated shelter. The roof was given a pitch of ½ in. per ft. and the top was given a float finish. Screened ventilators were left in the wall under the roof on either end of the reservoir. The area of the roof is 8 967 sq. ft. The covering of the reservoir was done by the Municipal Engineering Division under the direction of the Municipal Engineer, George W. Green, at a total cost of $12 823.74.

Before each section was placed in service it was cleaned by a gang and then filled with filtered water to which 20 lb. of copper sulphate were added, equivalent to about 4.5 parts per million. After standing for about 36 hr. the water was run to waste and the walls and bottom of the section flushed with filtered and disinfected water, after which it was refilled and placed in service.

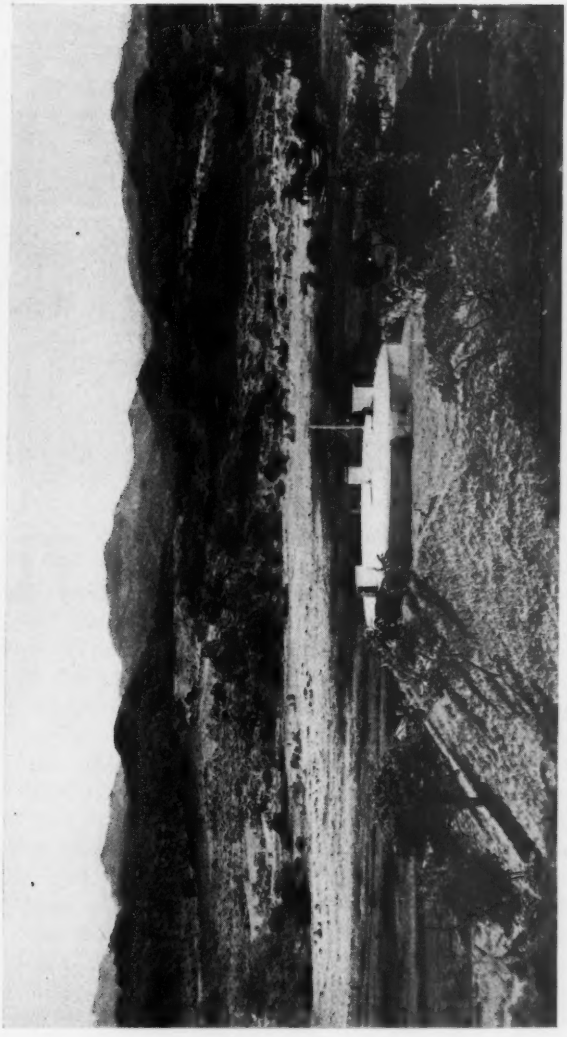

FIG. 6. — LOW SERVICE RESERVOIR AFTER CONSTRUCTION OF ROOF IN 1921.

After the roof over each section was completed and the reservoir as a whole was thrown into service no trouble was experienced from the multiplication of bacteria or from the development of algæ in the stored water.

Table No. 3 shows the bacteriological characteristics of samples of water collected from the distribution system during the first five months after the completion of the roof. If this table be compared with Table No. 2 the improvement effected by covering the reservoir is clearly evident. Other samples of water collected from the water standing in the reservoir yielded counts which correspond closely with those from samples collected from the high-service reservoir.

The improvements effected by the covering of this reservoir may be summarized as follows:

1. The maintenance of the filtered and disinfected water in the same condition in which it leaves the purification plant by:

   a. Preventing the entrance of dust, bird droppings, leaves and other foreign matter.

   b. Preventing the growth of algæ.

2. The elimination of frequent cleanings of the reservoir which means that the maximum storage capacity of the system is always available in case of a shutdown of the purification plant.

3. The lessening of the danger of the pollution of the reservoir by the gang engaged in cleaning it or by trespassers.

4. The water will enter the distribution system at a lower temperature.

When the senior author took charge of the purification of the water supplies in 1914 he anticipated that the multiplication of algæ in this reservoir, in view of the favorable temperature conditions, would be a continuous source of trouble but, as shown above, it was not until 1921 that vigorous growths of Mougeotia suddenly appeared and developed into a nuisance, not only to the consumers but to the maintenance force as well, on account of the frequent cleanings. If this reservoir had not been seeded with Mougeotia, probably by birds, it might have run on for several years without any trouble developing from multiplication of algæ with the exception that the deposits on the walls would cause an increase in the bacterial content of the water. The frequent daily changing of the water in the reservoir, the scarcity of organisms in the filtered water entering the reservoir, and their exposure for a few minutes to the dose of chlorine added to the water leaving the purification plant, were undoubtedly important factors in restraining the multiplication of the organisms entering the reservoir. On the other hand there is no reason, except that of luck, why the reservoir was not seeded at an earlier date, either by birds or by the wind, with some organism which like Mougeotia would have found an ideal environment.

In Kingston, Jamaica, the effluent from the slow sand filters is stored in uncovered basins and a luxuriant growth of algæ was seen by one of us

(G. C. Bunker) during a visit to the two filter plants. Detached pieces of the growth work their way into the service pipes of the consumers and cause complaints. In Cartago, Costa Rica, there are two uncovered reservoirs in which spring water is stored which are cleaned each week on account of the rapid multiplication of algæ and the collection of dirt which blows into the water from the surrounding streets. The mean air temperature averages 63° F.

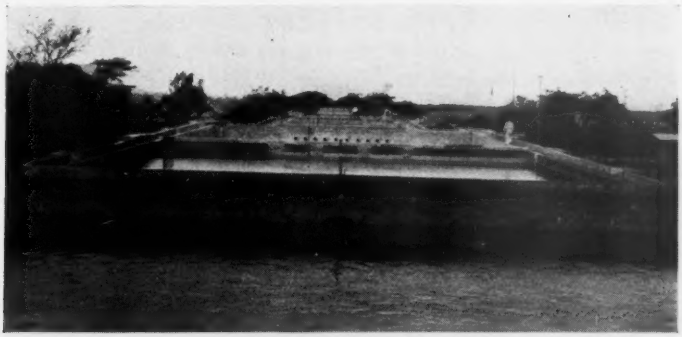

FIG. 7. — OPEN RESERVOIR IN SAN JOSE, COSTA RICA, 1921.

San Jose, the capital of Costa Rica, is also supplied with spring water which is carefully protected against light and exposure to dust until it reaches the city where it is discharged into an old reservoir, consisting of five uncovered tanks. The spring water is stored in three of the tanks while polluted river water for irrigation purposes is stored in the other two tanks. All connections between the two sets of tanks have been removed. The tanks in which the spring water is stored are cleaned each week on account of vigorous growths of algæ. In this case one of us (G. C. Bunker) agreed with the Municipal Engineer that it would be best leave the reservoir uncovered because later on some one in power might take advantage of a roof to increase the supply of water by making a connection with the tanks in which the river water is stored while if the reservoir remains uncovered such a connection may be easily detected. Eventually the river water will have to be stored in a separate reservoir which will allow the use of the entire reservoir for the spring water and thus permit the construction of a roof. The two other reservoirs in the water-supply system, used for the collection of the water from the springs are well built and covered.

At least the conclusion may be safely drawn that while an uncovered reservoir in the Tropics may be used for some time, several years perhaps, for storing filtered water without affecting its quality, it is certain, sooner or later, that a multiplication of algæ with accompanying troubles will occur. It is useless to make a prediction as to how soon a multiplication

of algæ will start in a new uncovered reservoir in which filtered or ground water is stored, with the idea that a roof may be placed over it later on in order to reduce the initial cost.

On account of the disgraceful situation which the Board of Aldermen of St. Louis, Mo., has allowed to develop through their misdirected opposition to the covering of the open basins for the storage of filtered water, thereby bringing an unenviable notoriety to an otherwise first-class water supply and arousing suspicions as to its potability among visitors to the city, we feel that it is advisable to bring out certain facts at some length in order to increase the value of our paper to those who may be contending with a similar problem in smaller communities. One of us (A. G. Nolte) while at the Chain of Rocks filter plant (St. Louis, Mo.) originated and conducted a series of observations to determine the extent of bacterial pollution of the water in these open basins as a result of dust falling on the surface. The following description of the work as well as Table No. 4 were taken from a report published in 1916.[7]

"During September and October analyses of the air at the basins at Baden and Bissell's Point were made. These analyses were made to determine the extent of bacterial pollution of the water in the basins caused by the deposition of dust particles containing bacteria on the surface of the water.

"Baden basin is located close to Broadway, and although a brick wall is placed between it and the street, there is a great deal of dust and dirt carried over onto the surface of the water. This is especially true in dry weather when traffic is heavy. The only analysis made at Baden was made on a damp day when traffic was light, due to the fact that it was a holiday.

"The basins at Bissell's Point adjoin the west approach of the Merchants Bridge on the south and the Burlington tracks on the east. Either of these lend to the pollution of the clear water in these basins under certain conditions. A strong wind from the south at a time when a long train of cattle cars is passing over the approach contributes materially to the pollution of the basins. At the time of the analysis on the 13th of September, under conditions shown in the table, there were in addition to large numbers of bacteria, soot and dust, many hundreds of chips of wood, some several inches in length, blown into basin No. 1.

"In order to preserve the high quality of the water now leaving the filter plant, it will be necessary to cover the basins at Baden and Bissell's Point. This will be necessary not only to prevent pollution by the air-borne bacteria, but also by surface drainage, by the eggs or larvæ of Chironomus and by the possibility of algæ growths.

"The method of analysis was as follows: Wooden trays containing six solidified agar plates were floated on the surface of the water when calm or held a few inches above the surface when choppy. The positions of the trays during the various tests are shown in the table. The plates, each 6.92 sq. in. in area, were exposed for various intervals of time, then covered and incubated at 37° C. for twenty-four hrs. before being counted. The results are expressed in number of organisms deposited per square foot of surface per minute.

"In addition to the agar plates, plates of Endo's medium were exposed. Though some growth took place, no colon colonies were found."

TABLE NO. 4.

BACTERIAL AIR ANALYSES AT BADEN AND BISSELL'S POINT RESERVOIRS.

Date of Collection. 1915.	Location of		Weather Conditions.		Local Air Disturbances During Exposure.	Organisms Deposited, Number per Sq. Ft. Reservoir Surface per Min.	
	Reservoir.	Trays of Plates.	Before Exposure.	During Exposure.		37° C. Organisms.	B. Coli.
Sept. 6.	Baden.	North, east and south corners, West wall. Center of basin.	Cloudy. Foggy. Rain.	Warm, sunshine. Slight wind from south-east.	None apparent.	45	0
Sept. 13	Bissell's Point.	3 at intervals along south wall. 2 at intervals along north wall.	Dry, sunshine. Strong wind from south.	As before exposure.	Three trains, totalling 50 cars, passing over Merchants Bridge approach. Wood and soot blowing into basin.	315	0
Sept. 21	Bissell's Point.	3 at intervals along south wall. 2 at intervals along north wall.	Cool, dark. Considerable wind from south.	As before exposure.	Two trains of passenger cars, totalling 16 coaches, passed over approach. Considerable cinders blown into basin.	75	0
Sept. 29	Bissell's Point.	3 at intervals along east wall. 2 at intervals along west wall.	Cool, dark. Slight wind from east.	As before exposure.	Four trains, totalling about 60 box cars and passenger coaches passed over approach.	40	0
Oct. 5	Bissell's Point.	3 at intervals along east wall. 2 at intervals along west wall.	Dark, cool. Moderate wind from north.	As before exposure.	One train passed over Burlington tracks.	69	0
Oct. 14	Bissell's Point.	3 at intervals along east wall. 2 at intervals along west wall.	Warm, cloudy. Moderate wind from north.	As before exposure.	One train (double header), totalling 40 box and coal cars, passed over approach.	55	0
Oct. 20	Bissell's Point.	3 at intervals along east wall. 2 at intervals along west wall.	Warm. Considerable wind from northwest.	As before exposure.	One train, composed of 40 box and coal cars, passed over approach.	57	0
Oct. 27	Bissell's Point.	3 at intervals along south wall. 2 in southeast corner of basin.	Warm. Slight wind from south-east.	As before exposure.	None apparent.	125	0

Table No. 4 shows that the number of organisms deposited per minute per square foot of the surface area of the reservoir varied from 45 to 315 per c.c.

In the annual report for 1920, page 58, August V. Graf, Chief Chemist, wrote as follows concerning these basins:

"In October the three south basins at Bissell's Point were taken out of service and cleaned. The water in these basins contained a great number of crustacea and diatoms. These basins being uncovered and exposed to the offal of trains passing over the Merchants' Bridge approach and to the dirt and dust of the dumps immediately south of the basins, cannot be kept free from objectionable matter."

"The usual and expected trouble from crustacea and algæ growths in the Compton Hill basins has been experienced during the year. These basins being situated as they are, with tops of the walls far above the ground, are practically free from outside contamination. As long as the basins at Bissell's Point are allowed to remain uncovered and thereby remain potential sources of contamination, which contamination is carried to Compton Hill, so long will we be unable to furnish a water during the summer months that will be free from objectionable organic growths. We assume that these organisms are harmless, having been declared so by eminent authorities, still that does not justify or mitigate our offense in compelling the people to consume a water that is objectionable both to sight and taste.

"The south basin at Compton Hill was treated three times with copper sulphate and the north basin four times during the summer of 1919. The organism count, not bacteria, was as high as 3 600 per c. c. and seldom was less than 200. The greatest number of crustacea present in any sample obtained was 10 in 500 c. c. The amount of copper sulphate added varied from 0.3 to 0.6 parts per million. After treatment the basins remained out of service for several days to permit the dead algæ and the copper sulphate to settle."

In his annual report for the year ending April 1, 1922, page 6, Mr. Wall states:

"For the seventh time an ordinance authorizing the covering of the storage basins at Baden and Bissell's Point was approved by the Board of Public Service on September 13, 1921, and forwarded to the Board of Aldermen with the recommendation that it be passed. This time it reached the Board of Estimate and Appointment, but there its progress stopped.

"During the summer of 1921, the water in these basins became so objectionable on account of the organic growths caused by exposure to the sunlight and to contamination from the dust and bacteria carried by the wind, that some of the basins were temporarily taken out of service, and others had to be emptied and cleaned.

"Many people complained of noticing these organisms in the water used in their homes, and assurances that they were harmless did not go very far towards reconciling them to its consumption."

In the same report, page 40, Mr. Cornelius M. Daily, Engineer-in-Charge, Supply and Purifying Section, expressed his opinion of the open basins in the following paragraphs:

"The clear water basins remain uncovered, a source of contamination from various agencies, although the Water Commissioner has introduced bills for appropriating money for this purpose every year since 1916. A comparison of the bacterial count of the water

which leaves the filter plant with the tap water will show a large increase in bacteria of tap water over the filtered water during the summer months which is the result of storage in the open clear water basins.

"We are using various means to keep the water in circulation in these basins which prevents to some extent the multiplication of organisms but are only makeshifts. It is impossible to set an uncovered barrel of water beside a dusty street and keep it pure by stirring. These basins have a combined area of 28.8 acres, which is equivalent to 1.57 sq. ft. for each inhabitant of St. Louis based on a population of 800 000. Who would be willing to have his supply of water in an open barrel whose area is 1.57 sq. ft. for 365 days in the year beside a dirty street? Would he be considered progressive if he left his barrel uncovered?

"The estimated cost of covering Baden basin is $110 000 and the basins Nos. 1 and 2 at Bissell's Point, $182 000."

Again on page 61 of the above mentioned report we find the comments of Mr. Graf on the same subject:

"The high bacterial count on agar, during five months of the year, of the water to mains and to consumers, was due to the fact that the basins at Bissell's Point and Baden being uncovered are subject to contamination especially after heavy rains. Samples of water obtained as the water entered Baden basin showed a count of 45 per c. c. while samples from the basin averaged over 2 000.

"Great numbers of snails were found in the basins during this time and some of them were examined in the laboratory. Five snails were cleaned, washed with sterile distilled water and placed in 500 c. c. of water in a flask. Immediately after placing in a flask, a sample of water was plated and showed a bacterial count of 2. After three hours, the count had increased to 11, and in 20 hours had reached 90 per c. c. In 2½ days the count had increased to 1 500 000. It is possible that the snails had some effect upon the water, helping to increase the number of bacteria."

"Chlorine was added to the water in these basins for several days but the method of adding the chlorine proved so unsatisfactory that it was soon discontinued. If the basins at Baden and Bissell's Point are to remain uncovered, machines for applying chlorine after the water has passed through these basins should be provided."

From Table No. 13, "Comparative Bacteriological Data. 1921-1922," on page 60, we find that the monthly averages of bacteria (developing on nutrient agar at 37° C., 24 hrs. incubation) in the filtered water as it entered the open storage basins, varied from 48 to 55 per c. c. during the months of June to September, inclusive. To this water there was added during the same period, monthly averages of 4.19 to 5.36 lb. of chlorine per million gallons equivalent to 0.50 to 0.64 parts per million of available chlorine. The same water after storage in the basins under discussion and as it was discharged into the mains running to the city, contained from 10 to 2 100 bacteria per c.c. Here we again have a case of bacteria multiplying in filtered and disinfected water while it was standing in uncovered reservoirs, similar to our experience with the low-service reservoir in Ancon, Canal Zone. By the time the above water had reached the consumers in St. Louis a further multiplication had taken place so that the monthly averages of the bacteria in samples collected in the city varied from 7 to 4 100 per c.c.

While mention was made in the 1921 annual report of great increases in bacteria after heavy rains, in the water stored in these uncovered basins, yet Table No. 6, "Comparative Bacteriological Data," showed no such startling figures as those given in the similar Table No. 13, in the 1922 report, so it appears to be reasonable to draw the conclusion that the conditions affecting in a detrimental manner the quality of the filtered and disinfected water stored in the uncovered basins at Baden and Bissell's Point, are rapidly growing worse.

A second application of chlorine to the water drawn from these basins and pumped into the mains leading to the distribution system proper in the city, would undoubtedly reduce the number of bacteria which developed in the basins and possibly prevent further multiplication in the mains, but it would not prevent the growths of algæ, crustacea and other organisms in the basins so that these would continue to pass into the mains and worry the consumer who does not want to see "bugs" in the glass of water he is about to drink.

Of the many covered service reservoirs in use the following are mentioned as examples.

UNITED STATES. — Arkansas: Arkansas City. California: Pasadena. Delaware: Wilmington. District of Columbia: Washington. Illinois: Quincy. Indiana: Indianapolis. Iowa: Dubuque. Louisiana: New Orleans. Maryland: Baltimore. Massachusetts: Brookline, Concord, Springfield, Wellesley. Michigan: Grand Rapids. Minnesota: Minneapolis. New Jersey: New Milford, Perth Amboy. New York: Albany, Ithaca, Watertown, Yonkers. Ohio: Columbus. Pennsylvania: Philadelphia. Virginia: Portsmouth. Wisconsin: Superior.

CANADA, — Montreal; Toronto.

ENGLAND. — Bradford.[8] London: Hampton, Honor Oak, Cross Hill, Burton-on Trent.

FRANCE. — Paris: Menilmontant, Montmartre, Montrouge, Belleville.[9]

PANAMA. — Canal Zone: Ancon.

As examples of the forced covering of service reservoirs, constructed originally without a roof, in order to eliminate troublesome growths of algæ, the following three cases are cited.

1. *Washington, D.C.*[10] In a paper on the covering of one of the reservoirs in this city John Gaub made the following statement concerning the construction of the roof:

> "Briefly, the cover was designed as a flat slab concrete floor to carry a live load of 75 lb. per sq. ft. The reservoir is in two compartments, and one of these was covered while the other was in service, thus causing no delay in the use of the water in that section of the city. The slab is 6 in. thick and is supported on 133 columns 16 in. square. The slab is made of a mix consisting of 1 part (Portland) cement, 2 parts sand and 4 parts gravel, and covers 44 600 sq. ft. The cost was about 37 cents per square foot."

2. *Dubuque, Iowa.*[11] An open concrete reservoir, capacity 7 500 000 gal., was built in this city several years ago at a cost of $82 000. Recently a concrete cover was placed over it at an additional expense of

$32 000 because it was necessary to clean the reservoir every ten days in the summer due to algæ growths, which was not only expensive but increased the fire hazard. There is a possibility of the arched top being used as a foundation of a community building or as a skating rink at some future date.

3. *Duluth, Minnesota.*[12] As a result of the investigation of the water supply of Duluth, Minnesota, by the State Board of Health, an open service reservoir is being covered in order to prevent the contamination of the water stored in it.

As examples of the covering of reservoirs at the time of their construction the following six cases are cited.

1. *Arkansas City, Arkansas.*[13] Capacity, 2 000 000 gal.; cost, $52 887.21; shape, circular; dimensions, 156 ft. inside diameter and 14 ft. deep to overflow weir; roof, 5-in.-reinforced-concrete slab with an 8 in.-slope from center to wall; beams, 10 by 15 in. spaced 12 ft. on center each way; columns, 10 by 10 in.; design, ring tension type with walls resting on a subfooting keyed into the rock stratum forming the bottom; the wall is separated from the footing by a specially-designed expansion joint, in order to eliminate cantilever stresses.

"The location of the reservoir being on public park property, it was decided before completion to utilize the top for tennis and volley-ball courts. The manhole openings and ventilators were so placed that ample space was provided for two tennis courts. Pipe couplings or sockets were installed in the roof slab for the net posts, and also sockets around the wall for posts for fencing the entire area."

2. *Perth Amboy, New Jersey.*[14] Capacity, 40 000 000 gal.; cost, $1 095-556; shape, irregular; dimensions, 900 ft. long by 230 to 370 ft. wide and 25 ft. deep; the roof and floor are of flat-slab reinforced-concrete construction, the roof being carried on reinforced-concrete columns; the embankment slopes within the reservoir are lined with plain concrete; the roof slab is covered with earth to a depth of $2\frac{1}{4}$ ft.

3. *Cross Hill Reservoir, London, England.*[15] Capacity, 30 000 000 gal.; cost, £79 000 (1913); shape, hexagonal; dimensions, each hexagonal side has 8 arches with a span of 30 ft. and a radius of 27 ft. $6\frac{1}{2}$ in., and a span and radius of 17 ft. $4\frac{1}{2}$ in. at the angles; the depth is 32 ft.; roof, 217 concrete domes, each 30 ft. in diameter; columns, 16 hexagonal concrete blocks, 18 in. deep and 3 ft. across between parallel sides, for each column or a total of 432.

The claim is made that this reservoir is of unique design and probably the most economical one ever constructed. The cost was about £2 800 per million gal. of storage as compared with an average cost of £5 000 for several small covered service reservoirs built for the London water supply.

4. *Indianapolis, Indiana.*[16] Capacity, 10 000 000 gal.; cost, $223-500, including pipe connections and appurtenances but excluding en-

gineering; shape, rectangular with rounded corners; dimensions, 254 by 542 ft. in plan by 10 ft. 8½ in. deep; roof, slab 9 in. thick designed for total live and dead load of 470 lb. per sq. ft.; 27 in. of filling was placed on the roof; column heads, 6 ft. 6 in. square extending 5½ in. below bottom of roof slab; columns, 24 in. in diameter, spaced on 18 ft. centers, making a total of 420; floor, groined-arch type of construction; circulation, two brick baffle walls insure uniform circulation of water.

The net area of water surface is 136 500 sq. ft. or 3⅛ acres, and the cost per million gallons stored, exclusive of piping connections, brick baffle walls and engineering, but including all earth work, was $19 150, which is equivalent to $1.415 per sq. ft. of water surface.

5. *Baldwin Reservoir, Cleveland, Ohio.*[17] This reservoir was only recently completed and is referred to by the Engineering News-Record as "perhaps the largest covered reservoir in America." Shape, rectangular; dimensions, 1 035 by 551 ft. in plan by 39 ft. deep; a division wall divides it into two basins of equal size; the floor is of flat-slab plain concrete; the roof is of the groined-arch panel type supported by columns 30 in. in diameter which are strengthened by stiffening walls forming a cross in each basin; special attention was given to the design of the inlets and outlets to ensure a good circulation of water.

6. *Montreal, Quebec, Canada.*[17 1-2]. Capacity, 50 000 000 gal.; shape, rectangular; dimensions, 512 by 525 ft. in plan by 15 ft. 6 in. deep; the roof and floor are of flat-slab reinforced-concrete construction, the former 6 in. thick and the latter 8 in. thick; there are 1 330 reinforced-concrete columns, 16 in. in diameter, spaced 12 ft. 6 in. apart, center to center, both ways; the footings are 5 ft. 8 in. square, of the tapered type, and extend upward above the basin floor a distance of 16 in.

The following four opinions from the writings of authorities on water supplies are quoted to furnish additional proof of the desirability of covering service reservoirs.

1. FULLER AND MCCLINTOCK.[18] "Where a water supply has been filtered and sterilized at considerable expense the best practice demands that it shall not be exposed to possible contamination in open reservoirs.

"In the construction of a new storage reservoir, such as is proposed at Thirty-Third Street and Jackson Avenue, provision should be made for covering the reservoir at the time of its construction."

2. HAZEN.[19] "The advantage of storing filtered waters in the dark, where they will keep entirely without deterioration, is so great that it seems certain that the present practice of covering will be continued until the present open reservoirs are all abandoned or covered."

3. WEGMANN.[9] "For the storage of ground water, or filtered water, the reservoirs should be covered, as solar light and heat cause growths of vegetation in such waters, such as algæ, which give the water a bad taste.

"Covered service reservoirs are built to protect stored water from (1) solar heat and light, which causes growth of vegetation; (2) from atmospheric impurities; and (3) against malicious pollution."

4. Don and Chisholm.[20] "It is an undeniable if somewhat disconcerting fact that filtered water is very liable to deteriorate if kept for any length of time before being distributed.

"Stored in an open reservoir, water of excellent quality may be invaded by plankton and micro-organisms which would render it unpalatable to the consumer.

"The obvious remedy for algæ and plankton growths is to exclude light by covering the clear-water reservoirs. This plan has been followed at many installations, as at Paris, London, Antwerp, Eltham (for pumped spring water), Nancy, Bedford, etc. Without this precaution it is difficult to maintain the purity of filtered water. Germs drop from the atmosphere or are carried by wind. Thus the reservoir becomes a gathering ground for micro-organisms.

"At most of the principal water works filtered water is stored in covered basins. The largest in the world is that for the Metropolitan supply at Honor Oak. Mr. Bryan, Chief Engineer of the Board, has expressed the opinion that filtered water should not again see the light till it issues from the consumers' taps."

Conclusions.

There is no doubt that the present-day tendency of water-works practice is strongly toward the covering of new service reservoirs, in which either ground or filtered waters are to be stored, at the time they are built, while the old uncovered reservoirs are gradually being covered after the misdirected influence of the amateur water-works men, present in every community, has been overcome by practical demonstrations of what it means to interrupt the water service of a reservoir by frequent cleanings for removing growths of algæ. Six very good reasons may be given for the covering of a service reservoir at the time of its construction, namely:

1. To maintain the water supply in the same condition of purity in which it leaves the purification plant or ground by:

   a. Preventing the entrance of dust, bird droppings, leaves, soot and other foreign matter.

   b. Preventing the growth of algæ.

2. To eliminate frequent cleanings of the reservoir which means that the maximum storage capacity of the system is always available in case of a shutdown of the purification plant or the pump station.

3. To lessen the danger of the pollution of the reservoir by the gang engaged in cleaning it or by trespassers.

4. To prevent loss by evaporation and to maintain the water at a uniform temperature.

5. To effect a saving in the cost of the roof which sooner or later must be constructed because it can be built at a minimum cost and with no interruptions to the water service.

6. Because an uncovered reservoir has no place in a well-designed water-supply system according to the collective expression of engineering judgment.

REFERENCES.

Wall, Edward E. Annual Report of The Water Commissioner of the City of St. Louis for the Year Ending:

[1] April 1, 1920, page 8.

[7] April 1, 1916, pages 57–58.

Annual Report of the Isthmian Canal Commission and The Panama Canal. Government Printing Office, Washington, D. C. For the Fiscal Year Ended:

[2] June 30, 1909, page 106; Plate 59.

[3] June 30, 1914, page 134.

[4] June 30, 1906, page 93.

[5] Davis, Carleton, E. 1906 Water Supply Problems on the Isthmus, Jour. N. E. W. W. Assoc., 20; page 252.

[6] Whipple, George C. 1914. The Microscopy of Drinking Water, Third Edition, page 47. John Wiley & Sons, New York, N. Y.

[8] Mitchell, Lewis. 1922. Bradford's Water Supply. Water Works Engineer's Office, Bradford, England.

[9] Wegmann, Edward. 1918 Conveyance and Distribution of Water, pages 342–355. D. Van Nostrand Company, New York, N. Y.

[10] Gaub, John. 1917. The Effect of Covering a Service Reservoir. Jour. A. W. W. Assoc., 4: 532.

[11] Jellison, L. J. 1922. Covering a Concrete Reservoir Saves Money. The American City, 26: 317.

[12] Filters for Duluth Water Supply considered unnecessary. 1922. Eng. News-Record, 89: 937.

[13] Smith, C. A. 1922. New Circular Reservoir at Arkansas City, Kansas. The American City, 26: 107.

[14] Johnson, Alexander. 1922. Constructing the New Covered Reservoir at Perth Amboy, N. J. Contractors' and Engineers' Monthly (154 Nassau St., New York, N. Y.), 5: 43.

[15] The Cross Hill Covered Service Reservoir. 1921. Water & Water, England (London), 23: 401.

[16] Mabee, W. C. 1922. The New Ten-Million-Gallon Covered Reservoir at Indianapolis. Eng. & Contracting, 57: 446.

[17] Building the Baldwin Reservoir, Cleveland Water Works. 1922. Eng. News-Record, 89: 916.

[17 1/2] New Filtered Water Basin for Montreal Water Works. 1922. Fire and Water Eng., 72: 1003.

[18] Report on the Water Supply of Kansas City, Missouri. 1921. By Fuller and McClintock, Consulting Engineers, and the Board of Review.

[19] Hazen, Allen. 1916. Clean Water and How to Get It, Second Edition. John Wiley & Sons, New York, N. Y.

[20] Don and Chisholm. 1911. Modern Methods of Water Purification. Edward Arnold, London.

Proc. Inst. C. E. 1883. 73: 1.

Coffin, Freeman C. 1899. Jour. Assoc. Eng. Societies, 23: 1.

Metcalf, Leonard. 1900. Trans. Am. Soc. C. E., 43: 37.

Wiggin, Thomas H. 1910. Eng. Record, March 12, page 298.

Gregory, J. H. 1913. Eng. Record, November 15, page 539.

Macqueen, Philip O. 1922. The Comparison of Concrete Groined Arches as an Aid in Their Design. Proc. Am. Soc. C. E., 48: 1665.

Discussion.

Mr. H. N. Blunt.* The character of covering of open reservoirs interests me. We had a similar condition, a small reservoir which, like many others at the time, was not covered. It had a wooden top designed and constructed, and the whole interior whitewashed. I should like very much to hear of any experience where a cover of this type has proved detrimental to the character of the water in a reservoir.

Mr. Caleb M. Saville.† The speaker was rather interested in water-supply conditions at Panama in 1909, and from then on for a few years, and he was interested in the statements in the paper about the seeding of the reservoirs, the sterile water reservoirs, by either the wind or by birds. At that time, when the speaker was there, the supply of drinking water was distilled water. All the water that was supplied to the people for drinking purposes was distilled. It was very noticeable that the first water that was drawn from the stills to be sent out, and which had come in contact with the air, showed a very large number of colonies of bacteria, due, as the author of the paper states, to being seeded from the air.

President Sanders. I think it would be rather interesting to know how the temperature of the waters in those tropical countries runs.

Mr. J. M. Diven.‡ I think the temperature of those waters runs somewhere about 70° to 80° in the reservoirs, if I remember right.

Mr. Robert Spurr Weston.§ I remember water with a temperature as high as 85° down there. I do not think the maximums are very much higher than some of our surface waters get here in the summer. But the average, of course, is very much higher. I know when we take a shower bath down there with the water at 85°, we think it is cold. The temperatures do get down to 60° on some of the surface waters. I should say, as a guess, from 60° to 85°.

Mr. Charles W. Sherman.¶ The presentation of this paper may perhaps cause a little consideration, on the part of those of us who live near Boston and who are interested in the Boston Metropolitan supply, as to what we may perhaps be confronted with if the extension of the Metropolitan Supply which is now being urged is not consummated, but instead, the so-called Southern Sudbury and the Cochituate waters, now particularly unused, are filtered, mingled with the surface waters, and stored in the existing open distributing reservoirs in or near the city.

Some of us already know, and others may have heard rumors, that it is not a perfectly clean water which is being distributed at the present time from Spot Pond and Chestnut Hill Reservoir, — the two main distributing reservoirs, — owing to dust and bird droppings. There is a great deal of

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† Chief Engineer, Board of Water Commissioners, Hartford, Conn.
‡ Secretary, American Water Works Association.
§ Of Weston & Sampson, Boston, Mass.
¶ Of Metcalf & Eddy, Boston, Mass.

trouble from sea gulls, which seem to frequent those waters, especially Spot Pond, I believe, and which the State law does not allow to be shot. Keeping those ponds sufficiently clean to furnish a good water is a pretty hard proposition.

Of course those reservoirs are large. Spot Pond started as a natural pond; Chestnut Hill Reservoir has now been in use something like sixty years; and the processes of purification by sedimentation and aëration, that are common in large ponds, do go on to some extent in those reservoirs, where they are dealing with surface waters.

But what the condition is going to be when we have filtered waters, which are, of course, in effect artificially-produced ground waters, is a subject for concern on the part of the people who are interested in that subject.

MR. H. C. STEVENS.* A few years ago the city of Perth Amboy, N. J., built a distributing reservoir. I was associated with Mr. Johnson in its design and construction. The reservoir has a capacity of 40 mil. gal. and stores ground water for an average period of four days, within the city limits, with highways on either side. To keep dust, leaves and other matter from being blown in, and also to prevent the easy possibility of the bodies of animals being thrown into such a reservoir, it has always been our thought, as with most of us here, no doubt, that such reservoirs should be covered.

* Consulting Engineer, New York City.

PUBLIC WATER SUPPLIES OF VERMONT.

By CHARLES P. MOAT.*

[*Read September 19, 1923.*]

Since 1899 when the Laboratory of Hygiene was established, it has been the policy of the State Board of Health to make frequent analyses of all water supplies that furnish water to ten or more families. These are the supplies that are classed as Public Water Supplies, although about 50 per cent. of them are under private ownership. During the last few years we have supplemented the laboratory examinations by field surveys as far as possible with our limited engineering staff.

When you consider that the total population of Vermont is approximately 350 000, a little less than half of which use water from our so-called public supplies and that many of these supplies are very small, you will see that our work of safeguarding these waters is far different and much easier than that of protecting supplies in more densely-populated places. Many of these supplies come from mountain springs and streams above habitation where the only human pollution can come from the careless hunter or fisherman. A field inspection on some of these sources often reveals deer tracks on the shore of a reservoir or stream well fenced to exclude cattle.

We have classed as public water supplies 106 supplies of our cities, towns and villages. Besides these supplies we aim to examine each season the waters used in our many vacation camps. We have approximately fifty of these camps in Vermont where 3 500 young people dwell for about two months in summer.

The sources of the 106 supplies are: — surface 31; ground 60; both surface and ground 15. Our laboratory data shows that the quality of many of these waters is unchanged in the past twenty years. Our data for 1920-21 indicate B. coli occasionally in 15 of the supplies, most of which is due to cattle pollution. Fifty-six can be classed as normal waters, 23 have received satisfactory natural purification, and 3 are classed as unsafe.

Our greatest improvement in water supplies was made in the few years following an order of the State Board of Health in 1904 which required the following cities and towns to obtain safe water.

Burlington taking raw water from Lake Champlain installed a filtration plant and its supply is now filtered and chlorinated.

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* Chemist of Vermont State Board of Health.

St. Johnsbury using raw river water and a filtered water from Stiles Pond abandoned the former for domestic purposes after a court decision in favor of the State Board of Health.

Swanton changed from the polluted water of the Missiquoi River to the safe water of Fairfield Pond.

Enosburg Falls which had two supplies, one from a polluted river and the other from a safe spring supply, tried with poor success the double supply in each house, the spring water supply being inadequate to furnish water for all domestic purposes. At the present time, this village is taking steps to install a safe supply for all purposes.

Vergennes did not see fit to change from its polluted river water and despite action in court (still pending) still has a badly polluted supply.

The changes in these supplies brought about a big reduction in our typhoid rate.

Since these changes there has been a general improvement in a number of our supplies.

The only supplies being treated at the present time are:

Burlington — filtration and chlorination.

St. Johnsbury — slow sand filtration.

Rutland — chlorination.

Montpelier — chlorination.

A brief description of the supplies of our cities and large towns follows:

Burlington. Source — Lake Champlain. Filtered and chlorinated. Open storage reservoirs 6 500 000 gal. capacity — on hill above city. We get B. Coli pollution in our reservoir water during dry summer months which is accounted for by birds and dust from highway. Annual reports of our Water Department give account of this supply arranged in accord with our New England Water Works rules.

Vergennes. Polluted river water from Otter Creek — direct pumping system.

Winooski. Gravity supply from two open storage reservoirs supplied by springs, brook and four deep wells. Water is lifted from deep wells into reservoirs by compressed air using electric power for the compressors.

St. Albans. Gravity supply from two impounding reservoirs at No. Fairfax. One farm too near reservoir, although well kept up, impossible to avoid some wash from this place in spring thaws.

Newport. Gravity supply from Derby Pond. No direct pollution from few farms on watershed. Some boat and fishing on this pond.

Rutland. Gravity supply from mountain brooks and streams. Storage reservoir of 5 000 000 gal. Watershed populated and stream passes through farming country and along main highway. Chlorinated above storage reservoir.

Barre. Two gravity systems — with storage reservoirs supplied by small streams running through pasture land. Some chance for pollution from farms on one of these streams.

Montpelier. Gravity supply from Berlin Pond. City owns considerable land about pond but supply is open to pollution at pond and along stream to reservoir. Restrictions against bathing, boating and fishing on pond but have had trouble in enforcing them as they are contrary to local public opinion. New chlorination plant started to operate in July. Chlorinates direct to main below reservoir.

Middlebury. Gravity supply from springs and brook on mountain side. Springs are situated in uninhabited watershed. Brook which is used as auxiliary supply is open to pollution from road and few houses. Distribution reservoir of 1 000 000 gal. capacity.

Hardwick. Gravity supply from springs and streams flowing into storage reservoir. Watershed sparsely populated. Emergency supply from stream unsafe on account of highway and house drainage.

Island Pond. Gravity supply — 500 000-gal. storage reservoir on hills above town fed by springs in woods on mountain above reservoir.

Swanton. Gravity supply from Fairfield Pond. No direct pollution enters pond from few farms on water shed. Owing to poorly-constructed pipe line, there is difficulty at times in maintaining pressure.

Brandon. Gravity supply from mountain springs. Storage reservoir of 500 000 gal.

Fair Haven. Gravity supply from Inman Pond located in wooded land away from farms. Field survey shows evidence of fishing and picnic parties. Some algæ growth at times in this water.

West Rutland. Gravity supply from mountain springs and brooks. Storage reservoir. A spring in the village has been used in dry times but it is not sufficiently protected from surface wash.

Northfield. Gravity supply from mountain springs. 500 000 gal. reservoir.

Waterbury. Gravity supply from hillside springs above habitation 200 000 gal. reservoir. System sometimes fails in dry times.

Bellows Falls. Gravity supply from Minard Pond located in the hills above the village. No buildings on watershed. Proximity to town makes it tempting as a spot for picnic parties. Ice for village is cut on this pond.

Brattleboro. Gravity supply from Sunset Lake. There are a number of camps on shores of lake, but these are used by Brattleboro people and the Water Company has a caretaker to maintain sanitary conditions of privies, etc. Lake posted against bathing. From the lake the water flows in open brook through wooded and pasture land to open reservoir.

Windsor. Spring supply pumped by electric pump to storage reservoir of 300 000 gal.

Woodstock. Gravity supply — two storage reservoirs impounding waters from streams and springs. Watershed inhabited but there is no direct pollution from the farm buildings. Chance for cattle pollution.

You will note from the foregoing that there is nothing novel along engineering lines in these supplies, most of them being gravity supplies.

The analyses of the water from the various supplies throughout the state, may be found in the biennial reports of the State Department of Health.

Discussion.

Mr. Charles L. Pool.* I should like to ask if they have had any trouble in Burlington here with algæ, where the time of storage is not long enough or too long, or what the situation is?

Mr. Moat. No, we have not had any trouble. I think the water is admixed with fresh water often enough to take care of that. We do not get the taste and odors we used to get from our raw lake water. In those times we used to get a little taste and some odors, but at the present time we do not have them.

Mr. Frederic I. Winslow.† In this town you have a filtered supply from a surface source, uncovered. The present trend is towards covering this kind of supplies. Have you had any trouble here from taste and odors?

Mr. Moat. We have not had any trouble with them.

Mr. Winslow. Or growths?

Mr. Moat. Or growths. But covering the reservoir I think would do away with our accidental pollution on the hill, which I lay to birds and dust. But we have not had any trouble from taste and odor or growths in our supply.

Mr. Winslow. Then you would say you would only gain from very slight pollution by covering?

Mr. Moat. I think so. Are you as apt to get growths, taking the surface water and storing it in the open, as you are a ground water?

Mr. Winslow. No. In the report of Mr. Goodnough to the State, regarding the new Metropolitan Water Supply, he says, regarding covering filtered surface supplies, this is very important, but he nowhere says it should be done or ought to be done. I suppose it is a moot question whether you ought to cover a surface supply or not.

Mr. Frank A. Marston.‡ I should like to ask Mr. Moat a question. If I remember correctly, he mentioned several spring supplies by gravity. I known of one case where a town takes a number of springs into a supply by gravity, and they have a good deal of trouble from air getting in at the inlets at the springs. I was wondering whether the same trouble had been experienced in Vermont.

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* Concord, N. H.

† Division Engineer, Metropolitan District Commission, Massachusetts.

‡ Of Metcalf & Eddy, Boston, Mass.

MR. MOAT. I do not know anything about it if it has. It has not come to our attention. It has evidently been taken care of locally if they have had that trouble.

MR. MARSTON. Of course it would be a physical trouble rather than one of quality.

MR. POOL. Mr. Moat spoke of blaming occasional findings of B. coli. on wild animals. This is often a vague but reasonable assumption to account for findings of B. coli in supplies from streams with watersheds above habitations or pasturage. I had an interesting experience recently in this connection which serves as a definite illustration of B. coli from such a stream being due to deer. At East Conway, N. H., a few coli were found in such a stream. There was nothing on the watershed to account for coli except a " deer yard " on the banks of the stream, reported by the superintendent. I told him I should like to see it, as I could scarcely believe that evidences of enough deer to cause the trouble could be found. We visited the " yard " and saw the scant remains of a large amount of deer dung which had been dropped on the banks close enough to be washed into the stream. Blueberry pickers had been detailed to remove the dung from the banks of the stream and about two bushels of the material had been picked up and placed in a pile below the dam. It had been on the ground, according to hunters, since last winter, and was dried up. I took some back to the laboratory and from the centers of some of the clumps, isolated B. coli readily. So there was no doubt that coli was coming from wild animals on this shed.

MR. M. N. BAKER.* Now that typhoid is so very much reduced, more and more attention is being given to other means of judging the quality of water supply, and every now and then there comes up something in regard to the coli or other bacteria which are found in water, which are probably due to birds or animals, or to dust blown into reservoirs, like the open reservoir here in Burlington.

Sir Alexander Houston, Director of Water Examinations, Metropolitan Water Board, London, England, in his annual report for 1922–23, details some studies he has been making on the infection from sea gulls and from fish in some of the many reservoirs that are used in connection with the Metropolitan Water Supply of London. In his attempt to determine whether the coli in the water were of human or animal origin, he made some extensive studies of bacterio-phages, but thus far nothing conclusive has come from these or his other attempts to determine whether the coli found in the water are of human or animal origin.

It is interesting for any of us who are familiar with water treatment in the United States to note in the yearly reports of Sir Alexander Houston the timid way in which he has been approaching chlorination and mechanical filtration. He took a plunge on chlorination at the time of the war because he was depending very largely upon storage for getting a safe

* Associate Editor, *Engineering News-Record.*

water supply, and to get the water to these storage reservoirs required a large amount of coal, and coal was at a premium during the war, and still is in England, as it is in this country. So he began chlorinating the water and thus reduced the pumpage to a considerable extent. Last year the London Water Board's coal bill was reduced $80 000 by chlorination and a lesser period of storage. In addition there was a saving on labor and other pumping expense. In earlier years the saving was larger, owing to higher prices.

But what seems almost comical to many of us here is the small-scale laboratory experiments on mechanical filtration that Sir Alexanter Houston is carrying on. It would seem on the face of it as if he was utterly ignorant of the extent to which mechanical filtration has been developed in America, but I do not suppose he is. He may feel quite confident of what mechanical filtration will do, but he has to convince a large Water Board, made up of delegates from the many cities and boroughs that are supplied with the London Metropolitan Water, and he has to go slowly, for he can't convince those people over there that just because Americans have done a thing on a large scale for a great many years it is safe. He is proceeding with these experiments, and he is not even using a coagulant, but he seems on the point, judging from his latest report of recommending to his Board a quite extensive use of mechanical filtration. He has a forward-looking mind, and his annual reports are among the most entertaining publications that come to my desk.

MR. J. FREDERICK JACKSON.* I should like to ask Mr. Moat a question. He spoke in his paper of suits that had been brought against different companies. My first question is, by whom were the suits brought?

And then he speaks again about regulations in regard to boating, bathing and fishing in some particular places. Will he kindly give us the limitations of the statute covering that? Does it cover the whole body of water, or is it restricted to certain portions of it?

MR. MOAT. The State Board of Health appeals to the Court of Chancery to enforce its orders, and then the case is tried in the Court of Chancery and then usually taken to higher courts. In the case of St. Johnsbury it was taken to the Supreme Court to determine the question whether the Board of Health could prohibit the use of a certain water, and the Supreme Court of Vermont ruled that we could. The bathing situation was also carried to the Supreme Court in the case of the Montpelier Water Supply, and was decided in favor of the State Board of Health. The boating and fishing case is still being fought out in the local courts of Montpelier. The first case that we brought against one of the men who had been boating and fishing is still pending. The Supreme Court sent it back to the lower court on account of some technicality in the Judge's charge, and it has not been re-tried. It is ready for re-trial at any time that the State's attorney wants to take it up.

* Director, Bureau of Engineering, State Department of Health, Connecticut.

MR. ROBERT SPURR WESTON.* I should like to ask Mr. Moat a question along those lines. Whether or not the State Board of Health makes regulations for the governing of reservoirs for the local water departments?

And another question related to that, — whether he has noted any effects of the increased automobile traffic upon the quality of surface waters?

MR. MOAT. We usually make those regulations if asked for by the local authorities, or if the supply has potential danger enough, or has shown up enough in our laboratory results, plus the field inspection, to make us think that regulation is needed. In some of our supplies the posting seems to be done by the head of the local water department, but in others they have asked for a special ruling of the Board, giving them a notice prohibiting bathing, boating or fishing, or trespassing, and so forth, on their watershed, or the particular pond or reservoir that is in question. That is done by a special rule being made by the Board, and a notice to that effect being sent out and posted.

I have not noticed any additional pollution from the automobile traffic, but I expect to at any time. Our Rutland supply has worried us until we chlorinated it, and much more since we have the volume of automobile traffic coming over the main highway along which the Rutland supply runs. But since that supply has been chlorinated we feel a great deal safer about it than we used to. But I haven't any actual results that show that the automobile traffic has tended to pollute our supplies. I put the automobile traffic in the same class as the careless fisherman and hunter, and think they need very careful watching. I think that the streams that are available to that traffic should be well posted to show that it is a domestic water supply, if we do not do anything further.

*Of Weston & Sampson, Boston, Mass.

THE SUBMARINE PIPE LINE BETWEEN PORTLAND AND SOUTH PORTLAND, MAINE.

BY HARRY U. FULLER.*

[*Read September 19, 1923.*]

The city of South Portland is situated across the harbor from Portland. It has a population of 8 250, and uses about 1¼ mil. gal. of water daily.

The South Portland municipal water supply was built in 1892. A 12-in. main about 5 mi. in length carries the water from the Portland supply main to the heart of the city of South Portland. A standpipe with a capacity of 600 000 gal. was built near the center of the city, and the service was satisfactory until within a few years.

During 1920 and 1921 measurements of the use of water in different parts of the system, using a portable Simplex Pitometer, showed the necessity of not only improving the gridiron system, but of supplying a larger quantity of water in the more thickly settled parts of the system as a fire-protection measure.

Investigation of possible methods of supply indicated the advisability of laying a submarine pipe line across the harbor on the downstream side of Portland Bridge. It must be far enough from the bridge piers not to endanger them, and from the fender piers and electric cables to give room to work.

Two submarine power cables were moved upstream by having the diver attach lines at intervals of 50 ft. and pulling them alternately. The cables were moved about 20 ft., at a cost of about $200, without injury to them.

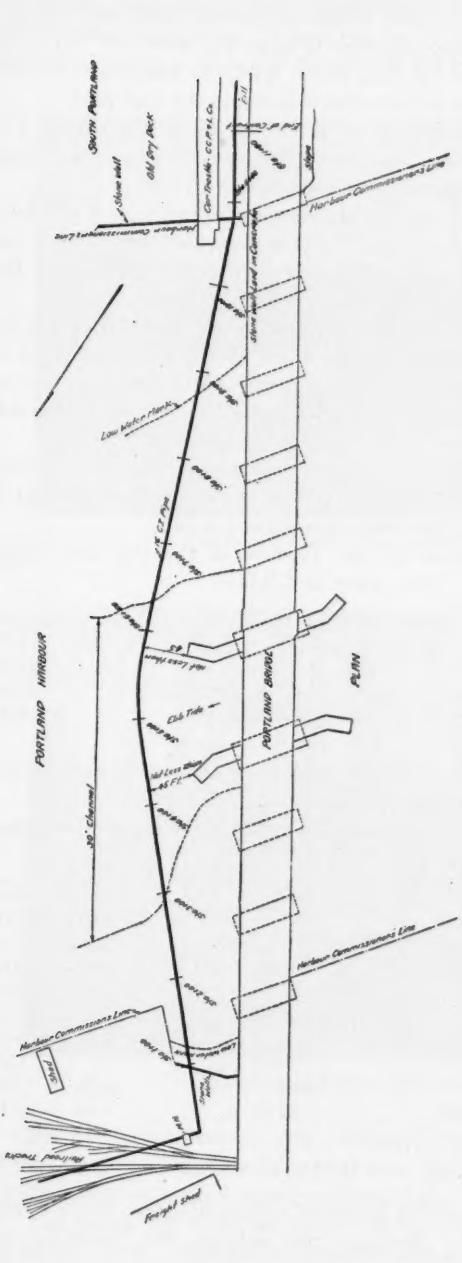
A study was made of the danger to pipes of freezing under sea water. The water in this harbor reaches 28° in the winter, and small pipes have been known to freeze when exposed to the action of the flowing tide.

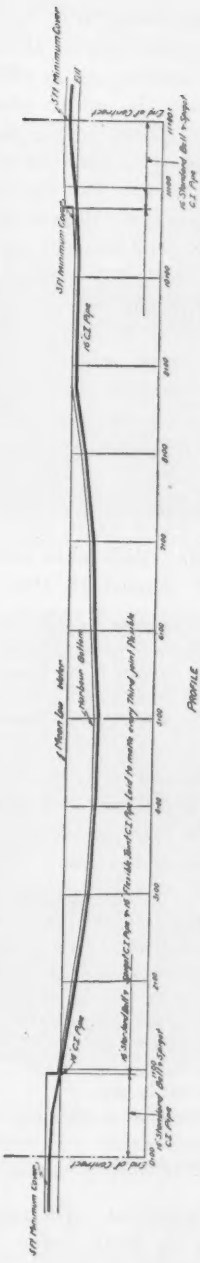
Cans of fresh water were buried at different depths below the surface of the flats, and temperature readings were taken of their temperature during the winter. This evidence showed that a cover of 6 in. of the blue clay forming the harbor bottom was sufficient to insulate the warmer fresh ground water from the sea water.

Owing to the possibility of an anchor fouling the pipe, it was determined to have a minimum cover of 3 ft.

Sixteen-in. Class D American Water Works Association specifications cast-iron pipe was purchased by the Portland Water District and delivered to the contractor on a wharf near the job. Flexible joints were inserted

* Chief Engineer, Portland Water District, Portland, Me.





PLAN AND PROFILE OF PIPE LINE. — Scale 1 in. = 200 ft. approx.

in the line every 36 ft., or, in other words, every third joint was flexible. The improved Boston Metropolitan type of joint was selected. This is a form of flexible joint in which the lead is held firmly by grooves to the bell of the pipe, the motion being between the spigot and the lead joint.

The quality of the material forming the bottom of the harbor was investigated by sounding with a $\frac{3}{4}$-in. pipe. There was found to be a small layer, not over a foot in thickness, of silt underlaid with clay.

A piece of concrete was cast the size and weight of a piece of 16-in. pipe 1 ft. long and laid in the bottom of a hole excavated 2 ft. deep in the mud near low tide. This did not settle over $\frac{1}{2}$ in. and indicated that the pipe line would not settle materially in the clay to be found there.

Scope of the Work. The contract consisted of moving two submarine electric power cables, of dredging a trench and laying in it 1 000 feet of 16-in. submarine pipe, of back filling with a cover of 3 ft., and of trenching and laying a section of about 70 ft. in length of 16-in. pipe at each approach to the submarine line to connect with the existing pipe lines.

The depth of water was 35 ft. at low tide in the channel. On the Portland shore it was about 3 ft. deep, and on the South Portland end of the line about 200 ft. of mud flats were exposed at low tide.

Bids. Bids were received by the Trustees of the Portland Water District, August 28, 1922. They were as follows:

Bennett Contracting Corp., 211 Commercial St., Portland, Me.	$12,837
Roy H. Beattie, 10 Purchase St., Fall River, Mass.	13,377
The T. A. Scott Co., 292 Pequot Ave., New London, Conn.	20,959
Bay State Dredging & Contracting Co., 62 Condor St., East Boston, Mass.	29,365
Andrew S. Merrill, 20 Garden St., Bath, Me. (Informal bid)	16,200

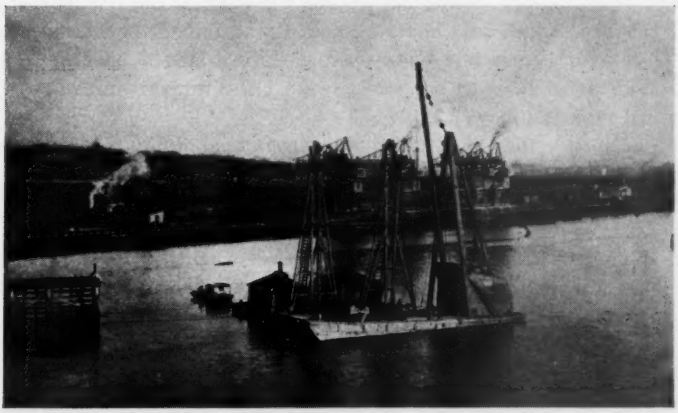
The contract was let to the lowest bidder. He was judged competent to do the work, and the outcome justified this action.

The following table shows the unit quantities and costs corresponding to the final estimate.

Item.	Quantity.	Unit Cost.	Total Cost.
Excavation on land	148 lin. ft.	$14.00	$2 072
Laying 16-in. cast-iron pipe on land	138 lin. ft.	1.75	242
Submarine excavation	1 007 lin. ft.	2.00	2 014
Laying 16-in. submarine pipe	1 007 lin. ft.	5.00	5 035
Back filling submarine trench	1 007 lin. ft.	.75	755
Moving electric cables	lump sum		200
Cutting through dock walls	lump sum		608
Lumber left in place	8 000 ft. B. M.	40.00	320
Gravel foundation submarine pipe	77 lin. ft.	2.00	154
Total cost of work			$11 400

Equipment. The contractor provided a derrick lighter 28 ft. x 80 ft. having an 83-ft. boom for dredging, pile pulling, pipe handling, and submarine back filling.

It was decided to lay the pipe by means of a chute suspended between two floating pile drivers. These two pile drivers were 20 ft. x 54 ft. and 24 ft. x 54 ft., each having 57-ft. pile-driving gins.



LIGHTER AND PIPELAYER LASHED TOGETHER.

SUBMARINE PIPE IN CRADLE.

The dredging was done with a clamshell bucket. A dump scow was used to carry the excavated material from the channel portion of the job and deposit it on the flats nearby at high tide.

The pipelaying chute was 138 ft. long and 3 ft. wide. A portion of this chute, 126 ft., was built to a true circular curve of 207-ft. radius. The

upper 12 ft. was built straight, deflecting downward about a foot at the upper end, below the tangent to the curve, to facilitate obtaining straight joints when making the joint. The chute was built up of 5 lines of yellow pine timber bolted side by side. The middle line, or keel, was an 8-in. x 14-in. timber, hewed out on the top edge to the true curve. On each side of this keel were lines of 8-in. x 12-in. timbers, bolted flat against the keel with 1-in. screw bolts passing through the 3 lines of timbers, spaced about 18 in. apart and staggered. These timbers were about 23 ft. long and broke joints well.

The outside timbers of the chute were formed of 6-in. x 12-in. timbers bolted flat against the 8-in. x 12-in. timbers and projecting somewhat above the others to form sides to keep the pipe on the chute. These timbers were fastened by $\frac{3}{4}$-in. machine bolts passing through the 5 lines of timbers, spaced about 3 ft. apart.

On the hewed top surface of the keel was spiked a 6-in. x $\frac{1}{4}$-in. iron plate the entire length of the chute.

The two floating pile drivers were lashed abreast of each other with a 6-ft. space between, the gins being ahead. This was accomplished with timbers fastened across the decks at both bow and stern and diagonal wire cable across the space between. To keep them from listing, an 8-in. x 10-in. timber was lashed between the gins 30 ft. above the deck.

In the space between the two drivers was placed the vertically-curved chute with its lower end resting in the bottom of the trench and the upper end slung between the two gins of the pile driver. As an additional precaution, the middle of the chute was supported by lines running over sheaves at the stern of the scows, and thence over one of the gin heads and counterweighted with a 2 700-lb. pile-driver hammer moving up and down with the tide.

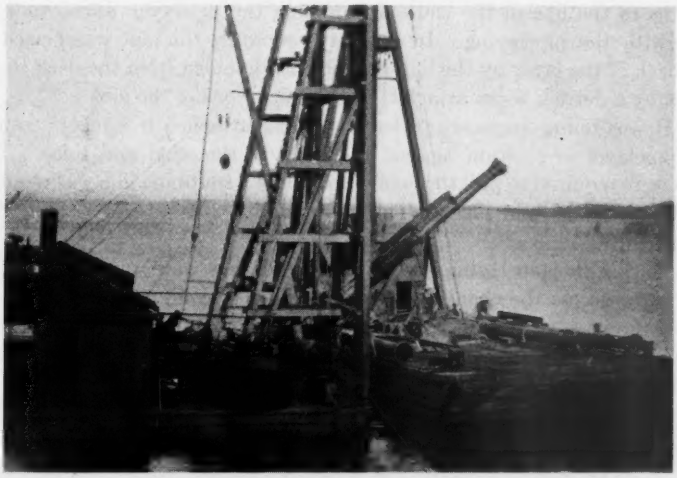
A long wire rope bale was attached to the lower end of the chute to provide a means of lifting it if it became necessary; but this proved to be a hindrance and not needed. In working on the flats, it became necessary to widen the space between the scows to 10-ft. and remove the timber lashed aloft between the gins that the scows might ground at low tide without undue strain.

The chute weighed about 10 tons, and was built vertically on a wharf, much like laying the keel of a boat.

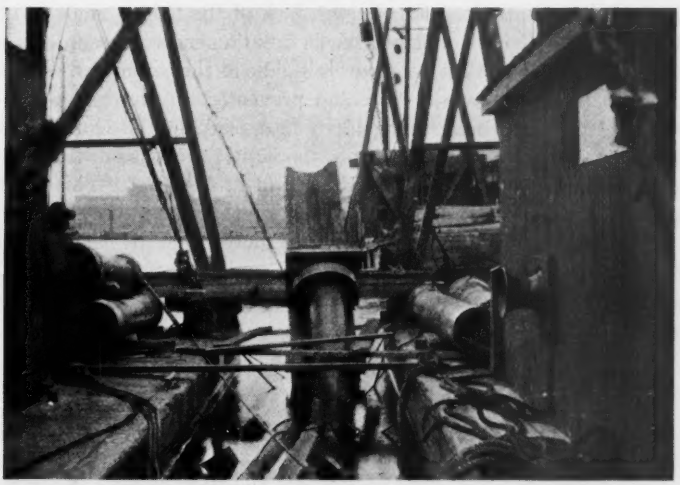
Laying the Pipe. The Portland approach to the line having been laid by ordinary land methods with the end of the pipe projecting a few feet beyond the face of the sea wall, and the lighter having dredged a considerable length of submarine trench, the pipelayer was towed into position. The lower end of the chute was placed in the trench a few feet beyond the end of the approach pipe.

Two pieces of pipe were then placed in the upper end of the chute and the lead joints poured and calked.

A line was then attached to the lower end of the pipe laying in the chute, and the pipe pulled down the chute by a hoisting engine located on



HOLDING UNIT OF THREE LENGTHS OF PIPE WHILE MAKING JOINT.



DETAILS OF PIPELAYER.

land. Another piece of pipe was then jointed into the upper end of the chute and pulled down the chute. This sequence of operations was then continued until the lower end of the pipe in the chute was inserted in the

bell of the approach line. A small sheet-pile cofferdam around this connection allowed the joint to be made in the ordinary way.

From this point the pipelaying consisted simply of adding successive lengths to the line in the chute and pulling the pipelayer along to keep pace with the pipelaying. In ordinary procedure the pipe was placed on the deck of the layer by the lighter, and then handled from the deck to the chute by a derrick boom attached to the side of one of the gins.

It was found necessary to have ten lines attached to anchors to hold the pipelayer in position against the force of the wind and tides. Two lines were required to pull the layer ahead, and a snubbing line was required to stop it at the right place. This snubbing line was attached to the pipe in the chute.

During the pipelaying, two spurts or dashes were made. The first spurt was across the channel, it being necessary to lay 192 ft. of pipe between the passage of ships without stopping. Right of way could not be obtained, but the channel had to be crossed when no vessel wished to pass. This was done between noon and 10 o'clock the same evening, and the operation furnished an excellent test of the possible speed of this method of pipelaying.

In preparation the lighter was lashed across the bow of the pipelayer, the three boats forming one unit. The trench having been properly excavated and inspected by the diver, only one other preliminary was attended to. Four sections of three pipes each and two sections of two pipes each were jointed together on the deck of the lighter, making units of 36 and 24-ft. in length. Strong backs or stiffeners, consisting of pieces of timber 6 in. x 8 in. x 12 ft. long with a saddle at the center and each end, were bound to the pipes with wire and prevented any movement at the joints while the units were being lifted into place in the chute. These units were handled by two whips from the lighter boom, and thus held in position while the lead joint was being run and calked. This method allowed a movement of 24 or 36 ft. for each joint poured in the chute.

The following tables were made from notes kept by the inspector. Table 1 shows the actual time required to make joints and pull the rig ahead, and Table 2 accounts for the entire elapsed time and explains the unforeseen delays.

Laying Submarine Pipe at Portland Bridge, November 9, 1922.

TABLE 1.

Showing Length of Time on Various Operations of Pipelaying.

Section No.	1	2	3	4	5	6	Total.	Average Time in Minutes.
No. of Pipe Lengths	3	3	2	2	3	3	16	
Length in feet	36	36	24	24	36	36	192	
Placing Section in Chute (min.)	8	10	12	8	10	7	55	9.1
Packing, Pouring and Calking Joint (min.)	19	14	18	20	18	16	1 hr. 45	17.5
Hauling, Rigging ahead (min.)	16	22	30	17	57	36	2 hr. 58	30.
Speed of Hauling ahead, feet per min.	2.25	1.64	.80	1.41	.63	1		1.28
Total	43	46	60	45	85	59	5 hr. 36	56

Laying Submarine Pipe at Portland Bridge, November 9, 1922.

TABLE 2.

Time Spent Laying Pipe Across Channel.

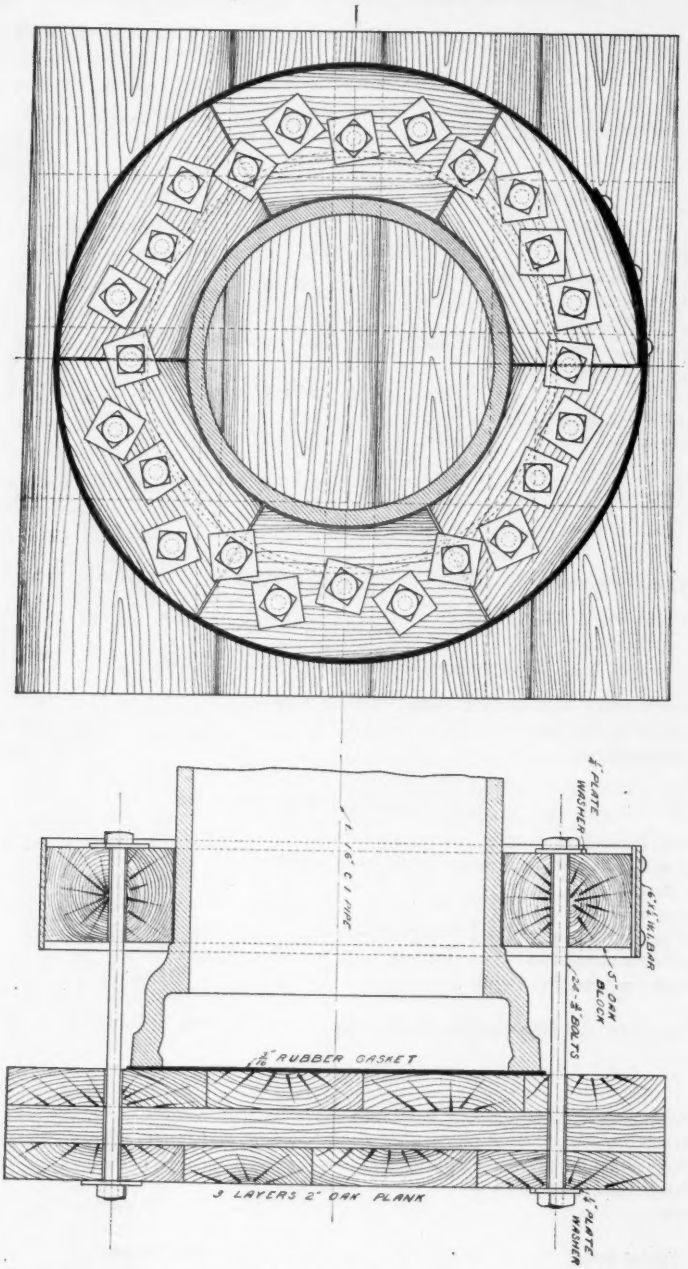
Time Mexican Petroleum boat passed through draw	12.17 P.M.
Time men quit at night	10.00 P.M.
Total elapsed time	9 hr. 43 min.

Time Actually Laying Pipe.

Moving lighter into position	33 min.
Moving rig ahead so that big bell would come in position in chute	26 min.
Placing 6 sections in chute	55 min.
Packing, pouring and calking 6 flexible joints	1 hr. 45 min.
Moving rig ahead 192 ft.	2 hr. 58 min.
Making lines fast for night	40 min.
Shortest time job could have been done	7 hr. 17 min.

Time in Delays.

Delay caused by yoke catching over stub in bottom of trench	1 hr. 20 min.
Delay waiting for diver to get into suit	35 min.
Delay putting on strong back	16 min.
Lunch	15 min.
Total delay	2 hr. 26 min.
Total elapsed time	9 hr. 43 min.



DETAILS OF PLUG FOR 16-inch PIPE.

The second dash was made in order that the scows should either float freely in the channel or if grounded should be on fairly level flats free from large rocks. It was necessary to put in 7 lengths of pipe while the tide was rising and before it had fallen more than a few feet on the following ebb. This was successfully accomplished. After leaving the channel, and as the depth of water became less, the upper end of the chute was carried ahead with reference to the floating pile drivers and lashed in its new position. This was necessary in order that the bottom of the trench should not get too far from the tangent with the bottom of the curved chute. This was done three times and 23 ft. cut off from the upper end each time, leaving the chute 69 ft. long for its journey across the mud flats.

When a point was reached where the end of the pipe was about 40 ft. from the South Portland sea wall, it was held by a tackle and the chute pulled out from under it. A buoy was then fastened to the end of the pipe and it was lowered into the trench while a hole was made through the sea wall and the remainder of the trench excavated. The submerged end of the pipe was then raised and a section of 3 pieces of pipe previously jointed was connected in place. From this point the work was above low tide and done by ordinary land methods.

Testing. The specifications required that the leakage should not exceed 16.8 gal. per joint per 24 hr. for submarine joints, and 8.4 gal. per 24 hr. for land joints at a pressure of 150 lb. per sq. in.

A cap was made to fit the open bell end of the pipe while testing the line. It was composed of three layers of oak plank laid at right angles to each other and well spiked together, the whole cap being 3 ft. square. Between this cap and the pipe a sheet rubber gasket was placed.

Around the pipe and back of the bell was a collar of oak blocks 5 inches thick held in position by an iron ring 6 in. wide. Holding the cap to the collar were 24-$\frac{3}{4}$-in. machine bolts.

The line was tested three times during construction with the following results:

1ST TEST.

18 submarine joints	@ 16.8 gal. =	302 gal. per day.
10 land joints	@ 8.4 gal. =	84 gal. per day.
Allowable leakage		386 gal. per day.

The actual leakage was 5 400 gal. per day, or 14 times the allowable leakage.

2ND TEST.

54 submarine joints	@ 16.8 gal. =	907 gal. per day.
10 land joints	@ 8.4 gal. =	84 gal. per day.
Allowable leakage		991 gal. per day.

The actual leakage was 4 280 gal. per day, or $4\frac{1}{3}$ times the allowable leakage.

3RD TEST.

84 submarine joints	@ 16.8 gal. =	1 410 gal. per day.
19 land joints	@ 8.4 gal. =	160 gal. per day.
	Allowable leakage	1 570 gal. per day.

The actual leakage was 2 540 gal. per day, or 1.6 times the allowable leakage.

The line was evidently growing tighter with time, and no attempt was made to calk the pipe under water.

Several months after the pipe line was completed, a further test was made by closing a valve on the South Portland approach to the submarine line and allowing the water to enter the Portland end of the line through a 2-in. meter. The leakage was found to be negligible.

Cost. The amount of the Bennett contract was $11 400. This was in payment for providing everything except the pipe and doing all the work necessary to complete the job.

Very good records were kept as the job progressed, showing the cost of the different items of work. They may be summarized as follows:

Dredging the trench, $2.00 per lin. ft.

Laying the submarine pipe, $5.00 per lin. ft.

Back filling the submarine trench, 75 cents per lin. ft.

While this work was progressing, abnormally good weather prevailed, and less than the usual number of unforeseen troubles to be expected on a job of this kind were encountered. While the contractor did not lose any money on the job, he did not make a profit proportional to his risks, or, in other words, his contract-price was too low, and he was fortunate not to lose.

Preliminary work was started the first week in September, and the job was entirely completed on December 22, 1922.

Personnel. The construction of this pipe line was done under the direction of Harry U. Fuller, the Engineer of the Portland Water District, with Leonard Metcalf as Consulting Engineer.

James W. Graham is Treasurer of the Water District, and Alfred E. B. Hall acted as inspector.

Discussion.

Mr. Frederic I. Winslow.* In testing that line did you close the gate and then connect a lead pipe around the gate to the main?

Mr. Fuller. Yes.

Mr. Winslow. How are you sure the shut gate did not leak?

Mr. Fuller. We were not sure. If there had been any leakage on the far end, our meter would have registered more, I should anticipate.

Mr. Winslow. Suppose the gate did not quite shut, was just open by a hair, we will say, and there was a leak in the pipe; the water might have passed through under the gate valve and not shown on the meter.

Mr. Fuller. I get your point. At the time that we closed the gate on the far end we emptied the pipe beyond the gate of water. We were putting a blow-off in at that time, so that there could not be any leakage from the far end into the pipe. There might have been a leakage from the big gate.

Mr. Winslow. We have usually tapped each end and then connected it up with the pipe and the meter, so that all water going into the test pipe must pass through the meter.

Mr. Fuller. We did that on the third test. This other test to which I referred was taken some little time later, after it was hooked up and we couldn't do it.

Mr. J. M. Diven.† How was the pipe protected from the action of salt water? Was any precaution taken to protect it?

Mr. Fuller. It was buried in a trench in the bottom of the harbor and covered with three feet of the blue clay that forms the harbor bottom.

Mr. Diven. Was the pipe protected from the action of the salt water in any other manner?

Mr. Fuller. We did not make any attempt to use anything other than ordinary coating.

Mr. Winslow. Did you state the weight of that pipe 12 ft. in length, the thickness?

Mr. Fuller. It was Class D pipe and had a special submarine joint. It carried 120 lb. of pressure.

President Sanders. Did you state, Mr. Fuller, how the back filling was done over this pipe?

Mr. Fuller. Through the channel portion we were not allowed to deposit our excavated material in the channel. In that section we put it into a scow and dumped it out onto the flats near low tide. Then after the line was satisfactorily in place we took up this mud from this pile in the water with our dredge and carried it back and put it down in the trench. But on either side of the channel, as we excavated the mud with our clam-shell bucket we swung the bucket around and deposited the mud perhaps

* Division Engineer, Metropolitan District Commission, Mass.

† Secretary, American Water Works Association.

50 ft. from the edge of the trench. We judged that would be far enough so that the tide would not carry it back into the trench before we wanted it there. Then when we came to backfilling we reached out, picked it up and put it back into the trench again. The scheme worked satisfactorily.

MR. R. W. WIGMORE.* I should like to ask if this sluiceway in which this pipe was sluiced, went down to the bottom — if that remained in the trench, or whether it was removed?

MR. FULLER. We pulled the chute along as we went. That chute was attached, the upper end to the floating pile drivers, and the lower end in the bottom of the trench which had been excavated, which was about 6 to 8 ft. wide and 5 ft. deep. It was somewhat rough in the bottom, because it was dug with a yard or a yard and a quarter clamshell bucket. But a diver goes with this chute, dragging it along in the bottom of the trench to smooth off the irregularities. So that the chute was dragged along, and the pipe slid down the chute and slid off the end of the chute into the bottom of the trench. When we got to the end of the line we cut off some sections from the upper end of the chute, pulling the chute ahead as we did so until only about 80 ft. or 60 ft. of the chute was in position under the pipe. Then we held the end of the pipe up with one line and took a side hold of the chute with the other line, and found we could pull it sideways very easily. Then the chute floated up to the surface. Then we lowered after that the end of the pipe down into its position in the trench.

MR. WIGMORE. I was very much interested indeed, Mr. President, in this paper which has just been read. A number of years ago in St. John we laid a pipe from the mainland to an island in the harbor. On that island at that time were the Federal Government emigration buildings. It was not a success, and about 10 or 12 years ago a flexible copper pipe was laid from the mainland to the island. That has given considerable trouble the past few years on account of not being buried, and small boats anchoring in that channel in rough weather have broken it in a number of places. We are considering the laying of a cast-iron main there, and I am very much indebted indeed to Mr. Fuller for the paper which he has read, and I can see very clearly where, with the experience that Portland has had, we in St. John can profit.

PRESIDENT SANDERS. I think Mr. Fuller's paper shows that he must have been considerable of a sailor, too, in addition to being an engineer, to handle that job.

MR. FULLER. The real answer is that I was not much of a sailor or an engineer, but I knew how to pick out good ones of both kinds.

MR. FRANK A. MARSTON.† If Mr. Metcalf was here I am sure he could offer remarks more to the point, perhaps, than I can, although I was privileged to have a part in the studies that went on in a preliminary way.

* Commissioner of Water and Sewage, St. John, N. B.
† Of Metcalf & Eddy, Boston, Mass.

One of the interesting questions which came up in the preliminary study of this proposition was the question whether the water in such a pipe line would freeze. Careful investigation was made, as far as possible, of available information on this subject, in connection with water pipes that had already been laid. The experience indicated that with pipe lines under salt water, larger than 6 in. in size, little trouble need be anticipated provided the pipe line is buried in the mud. The excellent experiments which were carried on by Mr. Fuller and his staff showed quite clearly that nothing need be feared in Portland harbor, under the existing conditions, with a 16-in. main and with the depth of covering of clay which it was proposed to give the pipe as a protection against anchors.

I do not think that I can add anything to the details which have been given so excellently by Mr. Fuller. I do want to offer a motion, however, Mr. President, which I believe is in order. Mr. Fuller has been very kind in coming and giving this paper, as a guest of the Association, and I offer a vote of thanks to him for his kindness.

(The motion was duly seconded and unanimously carried.)

SUB-SURFACE COLLECTING SYSTEM AND QUALITY OF WATER OF NEWTON, MASS.

By Edwin H. Rogers.*

[*Read September 19, 1923*]

Although the city of Newton, Mass., is within and a part of the Metropolitan Water District, which comprises nineteen municipalities in the eastern part of the Commonwealth, it is not a user of Metropolitan water except in emergency. Its municipally-owned-and-operated water works draws its supply entirely from underground sources located in the Charles River valley.

The collecting structures are located in a reservation in the adjacent town of Needham. The total area of the reservation is about 750 acres, but the portion thereof proven and demonstrated to be water-bearing gravel capable of practical development for yielding water does not exceed 150 acres, and it is within the limits of this area that the collecting system is located and draws its sub-surface supply.

This collecting system, as designed and constructed under the supervision of the city's engineering department, consists of a wooden collecting conduit built in 1889, a double line of open-joint 24-in. vitrified pipe laid in 1894, and a large concrete well constructed in 1911.

The wooden conduit is 4 ft. sq. in section, 3 769 ft. in length, laid level, with its invert grade line about 10 ft. below the average level of the river, which is in general from 50 to 75 ft. distant. This conduit is constructed of hemlock, green at the time it was used, and the planks composing its top, bottom and sides are laid with open longitudinal joints, permitting the water to infiltrate into the conduit from the adjacent water-bearing gravel. On either side of the conduit, $2\frac{1}{2}$-in. driven wells are located, reaching to depths of from 15 ft. to 80 ft. below the conduit and aid the flow of the ground water into the conduit. The top is generally 8 ft. below the ground surface.

From one end of this conduit, a cast-iron pipe line is laid under the river to the pumping station, which draws the water from the collecting system by gravity and pumps it directly into the distribution system. A ten-million-gallon reservoir located on top of one of the hills of the city controls the pressure, acting as a compensating reservoir and a reserve supply as well.

From the other end of the wooden conduit, a double line of open joint, 24-in. vitrified pipe is laid, and extends for 3 188 feet through nearly level land but little above the river level towards rising and hilly ground in a

* City Engineer

direction generally away from the river. The invert grade of these pipes is 2 ft. above the invert of the conduit at its start and rises on a slight grade, totalling 1.1 ft. in its whole length. They are laid 10 to 12 ft. below the surface of the ground. These pipe lines also have tributary 2½-in. driven wells, similar to the wooden conduit.

From the same end of the wooden conduit from which the pipe lines branch, is laid a tight conduit line about 3 570 ft. in length to the circular concrete well, 28 ft. in diameter, located about 500 ft. from the bank of the river, with its bottom about 32 ft. below the average river level. This well contains two 6-in. vertical, submerged, motor-driven, centrifugal pumps, which operate continuously a large part of the year and discharge about one million gallons of water per day into the wooden conduit through the pipe line by which it is connected.

The percentage of the supply contributed severally by the wooden conduit and the pipe lines is not known and difficult of determination; experiments are now under way to obtain this information approximately.

There are numerous manholes along both the wooden conduit and the 24-in. pipe lines, which afford an easy opportunity to observe the immediate ground water elevations. The elevations vary according to the seasons of the year and the conditions of rainfall, sometimes being only slightly below the river level and at other times from 4 to 5 ft. below.

A severe test of the adequacy of a ground water supply is increased use during summer months occasioned by shortage of rainfall at a time when the ground water table is low. The maximum draft on this supply in succeeding years for short periods of equal length has been increasing in a slightly diminishing ratio, in the period in question, while the total yearly comsumption has been growing in a somewhat increasing ratio.

The total monthly quantity which the city may take from this reservation is limited by statute. This amount is variable within certain limits, as determined and approved by the State Department of Health, and is regulated according to the rainfall.

Analyses of the water as averaged for each five-year period for the past 30 years are as follows:

PARTS PER 100 000.

Years.	Appearance.		Residue on Evaporation.	Ammonia.		Chlorine.	Nitrogen as		Hardness.	Iron.
	Turbidity and Sediment.	Color.		Free.	Albuminoid.		Nitrates.	Nitrites.		
1893–1897	None	.03	5.68	.0004	.0023	.41	.0238	.0000	2.6	.012
1898–1902	None	.02	6.04	.0004	.0030	.45	.0357	.0000	2.5	.004
1903–1907	None	.05	6.30	.0008	.0040	.45	.0362	.0000	2.7	.011
1908–1912	None	.01	6.36	.0005	.0028	.48	.0251	.0000	2.7	.006
1913–1917	None	.02	6.79	.0008	.0037	.54	.0395	.0000	2.7	.006
1918–1922	None	.01	6.00	.0006	.0031	.43	.0299	.0000	2.4	.008
Average	None	.02	6.20	.0006	.0032	.46	.0317	.0000	2.6	.008

An examination of the average yearly analyses, plotted graphically, shows no curve indicating a deterioration in quality, but on the contrary that the average quality has been practically constant throughout this period for which data is available.

This description of this city's collecting system and analytical data as to the water produced is offered as an instance of a ground water drawn from a favorable locality, which shows but little variation in quality through a considerable period, and it may also be noted as a supply that has not deteriorated by reason of increasing hardness or iron content under constantly increasing demands. The maintenance of its quality is unquestionably due to the fact that it has not yet been drawn upon beyond its safe capacity at any time, but past and present conditions indicate that the restrictions imposed by the State Department of Health as to the quantity to be drawn are safe to follow, and conservatism as to any increased use of this supply is to be favored.

REPORT OF COMMITTEE ON WATER WORKS LEGISLATION.

To the New England Water Works Association,

Your committee appointed to report upon the water-works legislation of the Massachusetts General Court of 1923, submits the following:

The legislation desired for the purpose of facilitating the financing of municipal water works in accordance with the reports presented by a previous committee on January 9 and February 13, was not obtained. It developed, however, that the Commission on Municipal Expenditures and Taxation had given more attention to the arguments of our committee than had been anticipated, and in its report to the Legislature (dated February 15, 1923, House Document No. 1240) recommended that cities and towns be permitted to borrow for a period of twenty years, for the construction of filter beds, standpipes and reservoirs; and for a period of fifteen years for laying and relaying street water mains eight inches or more in diameter. This recommendation, with the backing of the Commission, some of whose members were also members of the Legislature, received more consideration than our committee's bill, and with some changes was enacted into law as Chapter 303 of the Acts of 1923. Section 1 of this act is the only one which especially interests this Association, and is as follows:

> Section 1. Section eight of chapter forty-four of the General Laws, as amended by section eleven of chapter four hundred and eighty-six of the acts of nineteen hundred and twenty-one, is hereby further amended, by inserting after clause (3) the following new clauses:—
>
> (3a) For the construction of filter beds, standpipes and reservoirs, twenty years.
>
> (3b) For laying and relaying street water mains of six inches or more in diameter, fifteen years.

Although this does not give all the relief which was desired, it constitutes a long step in advance and materially simplifies the matter of financing water-works construction under the General Laws.

Previous legislatures have repeatedly refused to pass legislation making water rates a lien upon property. This year, however, the legislature overturned an adverse report of its committee and passed an act (Chapter 391, a copy of which is appended hereto) making water rates of municipal plants a lien upon the property in cities and towns which accept the provisions of the act.

The Legislature passed an act (Chapter 453) to provide access for the public to great ponds, but specifically excepted from the provisions of the act all great ponds which are used as sources of water supply, so that the act, which might by its general terms have constituted a source

of danger to many public water supplies, became innocuous as far as water works are concerned.

It is significant to note that the bill to prohibit shutting off water for non-payment of water rates was given leave to withdraw.

With regard to extension of the Metropolitan water supply, the Legislature authorized its Committee on Water Supply to sit during the remainder of the year to consider this subject, and the employment of an engineer to advise and assist it.

Several acts were passed, providing for the incorporation of water companies or allowing the formation of water districts, or extending the time in which certain towns or water districts might construct water works. These are of no general interest. It is significant to note, however, that special legislation authorizing cities and towns to borrow for water-works purposes, for terms longer than stipulated in the General Laws, or for purposes not covered by them, were passed, as shown in the following tabulation:

SPECIAL LEGISLATION FOR MUNICIPAL WATER WORKS LOANS, MASSACHUSETTS LEGISLATURE OF 1923.

City, Town or District.	Purpose of Loan.	Amount Authorized.	Term of Bonds, Years.	Chapter.
Acushnet	Extensions of mains and improvement of distribution.	$65 000	30	42
Belmont	Extensions of mains and improvement of distribution.	100 000	20	80
Billerica	Extensions of mains and improvement of distribution and storage.	50 000	20	293
Dartmouth	Extensions of mains and improvement of distribution.	100 000	30	188
Hudson	Relaying and extensions of mains and improvement of distribution.	50 000	20	215
Marblehead	Increase of supply, filters, extensions of mains, standpipe, etc.	200 000	30	2
New Bedford	Intake gate house, screen basin, and extensions of mains.	350 000	30	65
Revere	Streets, sewers and water mains.	250 000*	10	367
Rutland	Extensions of mains and improvement of distribution.	50 000	20	275
Shrewsbury	Extensions and improvement of water system.	25 000	20	77
Swampscott	Extending and relaying mains and improvement of distribution.	50 000	30	134
Unionville	Extensions of mains and improvement of distribution.	5 000	10	444
Worcester	Increasing supply.	750 000	20	274

* Only part of this is for Water Works.

It is interesting to note that there were thirteen such special acts, nearly all of which were for extensions of the main pipes and improvements of the distribution system. The loans authorized ranged from $5 000 to $750 000, and the terms of the bonds from ten years to thirty years.

It is to be hoped that the enactment of Chapter 303 will, to a considerable extent, make such special legislation unnecessary in future.

Respectfully submitted,

CHARLES W. SHERMAN
ALBERT L. SAWYER
GEORGE A. KING

Committee.

JUNE 16, 1923.

[CHAPTER 391.]

AN ACT RELATIVE TO THE COLLECTION OF WATER RATES.

Be it enacted, etc., as follows:

Chapter forty of the General Laws is hereby amended by inserting after section forty-two the following six sections: — *Section 42A.* If the rates and charges due to a city or town which accepts this and the five following sections by vote of its city council or of the voters in town meeting for supplying water to any real estate at the request of the owner or tenant, including interest and costs thereon, as established by local regulations, ordinances or by-laws, are not paid within sixty days after their due date, the same shall be a lien upon such real estate in the manner hereinafter provided. This and the five following sections shall not take effect in a city or town accepting the same as aforesaid until the city or town clerk files in the proper registry of deeds a certificate that said sections have been so accepted. Each register of deeds shall record such certificate in a book to be kept for the purpose, which shall be placed in an accessible location in the registry.

Section 42B. Such lien shall take effect upon the filing for record in the registry of deeds for the county where the real estate lies of a statement by the board or officer in charge of the water department that the rates and charges for water supplied to the real estate therein described, including interest and costs, to an amount therein specified, have remained unpaid for sixty days after the due date, and said lien shall continue for one year from the first day of October next following. Such statement shall contain the name of the owner of record of such real estate and a description thereof sufficiently accurate for identification. The register of deeds shall receive and record or, in case of registered land, file and register, said statement.

Section 42C. Within a reasonable time after filing such statement for record or registration, the board or officer in charge of the water department shall commit the unpaid account with his warrant to the collector of taxes of the city or town, and such collector shall forthwith send notice in accordance with section three of chapter sixty to the person designated in such warrant as the owner of record, and any demand for the payment of such account shall be made upon such person. The collector shall have the same powers and be subject to the same duties with respect to such unpaid accounts as in the case of the annual taxes upon real estate, and the provisions of law relative to

the collection of such annual taxes, the sale of land for the non-payment thereof and the redemption of land so sold shall apply to unpaid accounts charged upon real estate under sections forty-two A to forty-two F, inclusive.

Section 42D. Unpaid accounts under sections forty-two A to forty-two F, inclusive, shall bear interest at the rate of six per cent. per annum from the time demand is made under the preceding section, or from such earlier time after their due date as the city or town may by ordinance or by-law provide. Any such account committed to the collector under said section and remaining unpaid shall be added by the collector to the annual tax bill next to be issued, and the total amount of such bill shall be subject to interest under the provisions of section fifty-seven of chapter fifty-nine.

Section 42E. An owner of real estate aggrieved by a charge imposed thereon under sections forty-two A to forty-two F, inclusive, in addition to such remedy as he may have under section ten of chapter one hundred and sixty-five, may apply for an abatement thereof by filing a petition with the board or officer having control of the water department within thirty days after demand under section forty-two C, and if such board or officer finds that such charge is more than is properly due, a reasonable abatement shall be made; and except as otherwise provided herein, the provisions of chapter fifty-nine relative to the abatement of taxes by assessors shall apply, so far as applicable, to abatements hereunder. If such petition is denied in whole or in part, the petitioner may appeal to the superior court for the county where the real estate lies upon the same terms and conditions as a person aggrieved by the refusal of the assessors of a city or town to abate a tax.

Section 42F. An owner of real estate who, in order to prevent the imposition of a lien thereon or to discharge the same, has paid charges for water furnished to a tenant or other person who was bound to pay the same, may recover from such tenant or other person in an action of contract the amount of the charges so paid with all incidental costs and expenses.

Approved May 15, 1923.

PROCEEDINGS.

The following is a synopsis of such parts of the proceedings at the Burlington convention as appears to be of value for the record.

Forty-Second Annual Convention.

Burlington, Vt.
September 18, 19, 20, 21, 1923.

The Forty-Second Annual Convention of the New England Water Works Association was held at Burlington, Vt., September 18, 19, 20 and 21, 1923.

The headquarters of the Convention were at the Hotel Van Ness, where the technical sessions were held and where the manufacturers had their exhibits.

The Convention was called to order on September 18, at 2 P.M., by Percy R. Sanders, the President, who introduced Mr. Jules Simays, Chairman of the Burlington Water Commissioners.

Mr. Jules Simays. Mr. President, Ladies and Gentlemen of the New England Water Works Association: It is a pleasure for me, and my good fortune, to appear before you here as the Chairman of the Water Commissioners of the City of Burlington, and to offer to you — well, we haven't much to offer except Champlain water, of which you may use all you wish and take some home if you want — we have plenty of it.

I have the honor at this time of presenting to you the chief executive of our city, Hon. J. Holmes Jackson.

Address of Welcome by Hon. J. Holmes Jackson, Mayor of Burlington.

Mr. Jackson. Mr. Chairman and Members of the New England Water Works Association: This city is honored by your presence. I assure you that our citizens appreciate your coming to Burlington to hold your Forty-Second Annual Convention. I hope you will find our city beautiful for situation and cordial in its welcome, and I trust and believe you will find the inhabitants of this city on Lake Champlain worthy of your acquaintance and confidence.

For forty-one years your Association has been considering one of the most important subjects connected with the prosperity of the people — namely, the protection of the public from the ravages of fire, and the providing of a pure water for domestic uses. Experience and the inter-

change of thought through these years as to the means and methods for securing the best results has made your services of the greatest value to humanity.

I notice your officers have prepared an extensive program, and I am sure you will make commendable progress in your work. Pure water and fire protection are the real safeguards of the community and the chief supports of its existence.

I bid you a most hearty welcome to our city.

MR. SIMAYS. Ladies and Gentlemen: I also have the pleasure of presenting to you the President of the Chamber of Commerce of the city, Mr. Ordway.

ADDRESS OF WELCOME BY MR. C. D. ORDWAY, President Chamber of Commerce.

MR. ORDWAY. Mr. President, Ladies and Gentlemen of the Water Works Convention: I want to greet you with all the cordiality that can possibly be expressed in words, in the name of the Burlington Chamber of Commerce, to Burlington. We trust that your stay in Burlington will be made exceedingly pleasant by members of our organization.

Burlington is not the largest city in New England, quite, but we do boast of several things in Burlington that are pretty good size. One of those things is our water supply, which is practically inexhaustible — Lake Champlain. The other thing is that we can compete with any city, not only in New England but in the United States, in regard to the scenery and, I think, hospitality.

The Burlington Chamber of Commerce is a little bit unique in the fact that it is the only organization of its kind in the United States that has a thousand members to twenty-three thousand population. We leave that as a challenge until somebody disputes it, but as far as paid membership is concerned, I think it is the largest per capita organization of its kind in the United States. And this organization, while not every member is active, extends to you the greeting and the cordiality of its rooms, and anything that the Chamber of Commerce can legitimately do to further your organization and induce you to come to Burlington for future conventions we would be more than glad to do. We want to make Burlington a convention city, and we hope you will go away with such a pleasant taste in your mouth you will be glad to come back to us again in a very short time.

RESPONSE BY PRESIDENT SANDERS.

THE PRESIDENT. Your Honor, Mayor Jackson, and Mr. Ordway: I wish to thank you this afternoon for your welcome to your city to the members of the New England Water Works Association.

In 1895, twenty-eight years ago, the New England Water Works Association held its fourteenth annual convention in your city, and it was

probably the memory of that convention which prompted a desire in the minds of those of our members who were at that convention to come again to your city to hold our convention.

I made my first trip to Burlington on Friday, the 13th of April, to see what could be done in reference to holding the convention here, and I am glad to say that that particular day will hold no fears for me in the future in making any trip.

The chief aim of the water-works manager or operator is not, as is popularly supposed, to dig up and spoil good streets, although I will admit that they do their share of that. It is, however, in the first place their aim, and you as citizens go to any expense to carry it out, to provide a pure and wholesome supply of water for domestic purposes and for fire protection. You spare no expense to do this, and then when it is done you place these works under the control and management of water-works superintendents and engineers. It is the main purpose and aim of this convention, and of all the conventions of the New England Water Works Association, to furnish a program dealing with water-works construction, sanitation, and all the problems of water-works management, so that we may more intelligently deal with the problems that come up before us.

I personally feel that it is one of the best investments that any city can make to send its representative, in the form of its manager or superintendent or engineer, to attend these conventions, because in that way he can meet with his fellow members and discuss his problems with them. In most cases the water-works superintendent is the only man in his town in his particular line, and he very often runs up against problems that can only be solved by a conference with his fellow members.

I wish to thank you again, Mr. Ordway, and your Honor, Mayor Jackson, for welcoming us here to-day.

Presentation of Honorary Membership to Mr. John Ripley Freeman.

President Sanders. The first thing on the program this afternoon is the presentation of Honorary Membership to Mr. John Ripley Freeman. It is the custom of this Association from time to time to bestow the grade, if I may call it so, of Honorary Membership upon some one of its members who has attained particular prominence in his profession or through his long association with this New England Water Works Association.

I will now call upon Mr. Charles W. Sherman, who will present to Mr. Freeman this Honorary Membership.

Mr. Charles W. Sherman. Mr. President, this is the first time that this Association has undertaken to confer Honorary Membership in a formal manner at one of its meetings. It is very much to be regretted that Mr. Freeman is not present. I had looked forward to the privilege of presenting him personally to receive this honor at your hands, but as it appeared at the last minute that he could not be here, and as the ceremony of the

formal presentation of Honorary Membership is something well worth while to establish, with the hope it may be perpetuated, I have asked our past president, Mr. Saville, to accept the Honorary Membership on behalf of Mr. Freeman.

I have looked forward to the privilege of making this presentation of Mr. Freeman with especial pleasure because it was my good fortune, at the beginning of my work in hydraulic fields, to work for some time under Mr. Freeman, and it would therefore have been particularly interesting to me to bring him up for such a presentation.

Mr. Freeman's name is well known to all hydraulic engineers, and to nearly all water-works men, as one of the greatest of our American hydraulic engineers. His work, as many of you know, has been more in other fields than that of water supply — particularly in fire protection, water power, the Panama Canal, the canals of China, the Charles River Basin, and works of that character. The water-works problems which he has dealt with, and with the greatest success, are, however, numerous and of the first magnitude. They include services as Consulting Engineer for the water supplies of New York City, San Francisco, Los Angeles, Baltimore, Hartford, and a number of the other of our very large cities.

Mr. Freeman's technical writings are also well known to many of us. Probably the best known are his two papers — one on "The Hydraulics of Fire Streams," and the other on "The Nozzle as an Accurate Water Meter," which were presented to the American Society of Civil Engineers about thirty-five years ago, and which, although as old as that, still remain the standards upon which practically all computations of hose and nozzles are based. The substance of the first of these papers was presented, somewhat abbreviated, to this Association, and published in our JOURNAL as well.

From the water-works standpoint it remained for the paper which he presented to us only, entitled "The Proper Arrangement of Hydrants and Water Pipes for the Protection of a City Against Fire," to make the number of the JOURNAL in which it appeared one of the "best sellers" for the time being, and the edition was quickly exhausted.

Mr. Freeman has been President of the Boston Society of Civil Engineers, of the American Society of Mechanical Engineers, and the American Society of Civil Engineers; and the New England Water Works Association will honor itself by conferring Honorary Membership upon him.

MR. CALEB M. SAVILLE. Mr. President, Ladies and Gentlemen of the New England Water Works Association: I trust if Mr. Freeman has arrived that he will come forward. I realize what a crescendo performance it is for anybody to substitute on such an occasion as this, and especially for such a genius as is Mr. Freeman. I believe that by conferring Honorary Membership on Mr. Freeman this Association has honored itself by honoring him.

It is unnecessary for me to add in responding for him, to what Mr. Sherman has said of the professional work of Mr. Freeman. That is well known throughout the world. I should like to tell you, however, of some of his personal traits, and I should like to have you know of some of his helpfulness to others.

Some years ago I spoke to him of his helpfulness to others, and I shall never forget the nice way in which he said to me, " That is all right, Mr. Saville; I had just such a feeling as that myself one time, a good many years ago, and I mentioned it to" — I think it was Mr. Hiram Mills — " and he said to me, ' The best thing that you can do, if you feel that way, it just to pass it along to the other fellow.' " And that has been Mr. Freeman's way of doing — to pass the good things along.

He has been of service to our own profession, to our water-works men most particularly, because he has been a water-works man. His first work, I think, was in Lawrence or Lowell — I have forgotten which — and from there he went with Mr. Edward Atkinson with the Factories Mutual Insurance Company — I don't know as I am saying these just in order, but I am just giving you the main sketch — and it was the result of his personal labors there that brought forth that splendid organization, with its laboratory and the experimental work which has now been brought to such perfection that its results are the criteria for this class of insurance.

Since that time Mr. Freeman has gone forward, until his name as Mr. Sherman has said, is well known everywhere. He has not been satisfied with just doing one thing well, he has advanced in many lines of business and professional work; his best has always been ahead of him.

It was said when he was engaged as the consulting engineer on the Charles River Dam he worked night and day on his report. There was no let-up to it until he got it completed, and that report is really one of the finest pieces of engineering literature of its kind.

His recognition of the work of others also is a very, very helpful thing to young men. When he reads something in a technical publication or in the scientific papers, busy man though he is, he is very quick to write a letter calling attention to the good points in that writing. That is tremendously helpful to the younger men coming along to find that a man of Mr. Freeman's standing is willing and able to recognize what they have done. Mr. Freeman is a man of impartial judgment, too. A man of strong convictions himself, he is very willing to give credit for what the other fellow has done.

He has been a student and an investigator, and many of the results that he has brought forward are now the standard for water-works engineering in this country.

I do not need to go further in this matter. Mr. Freeman is known, and, as I say, in honoring him you have honored yourselves in giving him this membership in your Association and I thank you in his name for it.

Award of Dexter Brackett Memorial Medal.

President Sanders. It is the custom at the Annual Convention to make the award of the Dexter Brackett Memorial Medal for the most meritorious paper written and read before this Association during the past year.

I will now call upon Mr. Frank A. Barbour, who will, in behalf of the Association, present this medal.

Mr. Frank A. Barbour. Mr. President, Ladies and Gentlemen: Your Committee by unanimous vote has awarded the medal for the year 1922 to Mr. Charles W. Sherman. We were forced to this award by the merits of his paper on " The Proper Term for Which Water Works Bonds Should Run," although we were somewhat embarrassed in looking over the history of the founding of the medal.

In 1916 Mr. Sherman made a motion before this Association proposing that a fund be raised to provide a memorial to Mr. Dexter Brackett. He was a member of the committee which was appointed; he handled the finances, and it was largely due to his efforts that the presentation of this medal is one of our yearly events. Despite these evidences of conspiracy, however, and particularly as Mr. Sherman has had the modesty to restrain his capacity for some six years — he did not take it the first year, and he has waited until this time — we were forced by the merits of the paper to make the award as we have done.

The paper was written under pressure, as I happen to know. It was written for a definite object. The object was to provide a scientific basis for an argument before the Legislative Committee in reference to a question of interest to all water-works men. It was written by a busy man, and it is a good example of what a busy man can do under pressure.

Mr. Sherman, it gives me very great pleasure, sir, to present to you this medal, which ought to be particularly valuable to you because of your intimate association with Mr. Brackett.

Mr. Charles W. Sherman. Mr. President, Mr. Barbour, Ladies and Gentlemen: I think any member of this Association is justified in feeling proud of being awarded the Dexter Brackett Medal.

As Mr. Barbour has said, I had a part in establishing a memorial to Mr. Brackett and determining what its form should be, but I never for a moment thought at the time that the medal would come to me. In fact, I thought the probability was so strongly against it that I took advantage of my position as a member of the committee to get the company, which made the dies and struck off the medals, to strike off one for me at my expense, marked " Proof," so that I might have a copy of it. It is, therefore, especially pleasing to have finally obtained a medal which is really given to me and which I did not have to buy.

The award of this medal brings to mind once more the work which Mr. Brackett did for this Association. The number of men who knew him

and knew what he did in that line is gradually decreasing, and it may not be out of place to say a few words about that. An appreciation of his work of course was the main reason why the Association decided to establish this memorial, and why our committee studied the form which such a memorial should take.

Mr. Brackett was not one of the founders of the Association. The original conception was, I believe, with a Mr. Lyon, who was president in the very early days of the Association and then practically dropped out, and had very little influence on its future work. The real formation of the society and its early history, its life, depended mainly on two men, who have now gone, Robert C. P. Coggeshall and Albert S. Glover. They were practically the founders of this Association.

Mr. Brackett may be said to have formed the Association's character. He took an active part in its work from, say, after the first five years, practically to the time of his death, and I think was responsible, probably more than any other one man, for making it a society which really accomplished something. And it was in recognition of that work that the committee finally decided that, as a memorial to him, something which recognized papers which tended to advance water-works practice was the kind of thing that Mr. Brackett himself would appreciate if he could know what we were doing.

Looking back on Mr. Brackett's career and what he did for the Association, it is with a feeling of a good deal of humility as well as pride that I accept this medal.

Election of Officers.

President Sanders. Under the Constitution under which we are now working, the year of the New England Water Works Association closes with the close of the Annual Convention, and it is the duty of the President, one hour after the opening of the convention, to declare the polls closed unless there are some who still wish to vote. If all have voted who wish, I will declare the polls closed and will ask Mr. Gidley, the chairman of the committee, to announce the count of the tellers.

Report of Tellers.

Mr. Henry T. Gidley, *Chairman.*

Total number of votes cast..... 249

President.

(To serve one year.)

David A. Heffernan, Milton, Mass..... 246

Vice-Presidents.

(To serve two years.)

Theodore L. Bristol, Ansonia, Conn..... 244

(To serve one year.)

Stephen H. Taylor, New Bedford, Mass..... 242

Directors.

(To serve two years.)

George A. Carpenter, Pawtucket, R. I..... 242
Arthur E. Blackmer, Plymouth, Mass..... 232

(To serve one year.)

George W. Batchelder, Worcester, Mass..... 244
Frank Emerson, Peabody, Mass..... 227

Treasurer.

(To serve one year.)

Frederic I. Winslow, Framingham, Mass..... 245

The President. Gentlemen, you have heard the report of the tellers. You have chosen as your President for the ensuing year, Mr. David A. Heffernan, and I know you will all be pleased to hear a few words from Mr. Heffernan.

Remarks by President-Elect David A. Heffernan.

Mr. Heffernan. Mr. President and Members of the New England Water Works Association: My thanks are due you, gentlemen, for the honor you have conferred on me in selecting me to preside over the deliberations of your Society for the coming year. I value the compliment especially as coming from a Society such as this, and I hope that with your hearty coöperation we shall keep up the good work of the Association as it has been carried on in the past. I thank you.

MR. J. M. DIVEN. Mr. President, I have just read with a great deal of sorrow an announcement of the death of our long-time treasurer, Mr. Bancroft. I think that the Association should take some action and suitable resolutions should be prepared. Mr. Bancroft served this Association as treasurer for a great many years, well and faithfully.

SECRETARY GIFFORD. That has been taken care of.

PRESIDENT SANDERS. I think it would be well for the members present to stand a moment in silence in reverence to Mr. Bancroft.

(All persons present stand in silence.)

On motion of Charles W. Sherman, duly seconded, it was voted, that the Executive Committee be authorized to reappoint or to revive the Association's committee to work with a corresponding committee of the American Water Works Association, on Meter Standardization, if in the judgment of the Executive Committee it seems wise to do so.

MR. HENRY V. MACKSEY. Mr. President, I think it is only proper at this time that we should congratulate the officers who have conducted this convention so well for us, and our members, not only active but associate, who have contributed so largely to the success of this part of the convention, and also that we should express our appreciation and gratitude to the local people who have helped so much in making the affair pleasant and profitable to all of us. Therefore, I offer the following resolution:

"That the thanks of the New England Water Works Association are hereby extended to Hon. J. Holmes Jackson, Mayor of Burlington; to C. D. Ordway, President of the Chamber of Commerce; to the Burlington Water Commissioners; and to the other officials and employees of the city of Burlington, to the members of the Honorary Reception Committee, the Local Committee of Arrangements, the Ladies' Committee, and to all others who have given so generously of their time and means to make this a most successful convention."

(The motion was duly seconded and unanimously carried.)

MR. THEODORE L. BRISTOL. Mr. President, it seems to me the Water Works Manufacturers' Association has helped a great deal to make this a delightful and successful meeting, and I therefore want to present a motion of thanks to them.

"Moved: That the thanks of the New England Water Works Association are hereby extended to the Water Works Manufacturers' Association, and to all the members of the Committee who have contributed so much to the success of this, the Forty-Second Annual Convention."

(The motion was duly seconded and unanimously carried.)

The following reports of the Association were received:

Report of the Secretary.

September 1, 1923.

Mr. President and Gentlemen of the New England Water Works Association, — The Secretary submits herewith the following report of the changes in membership during the past eight months, and the general condition of the Association.

The present membership is 769, constituted as follows: 9 Honorary, 685 Active, and 75 Associate Members, there being a net loss for the year of 56. The detailed changes are as follows:

MEMBERSHIP.

January 1, 1923.	Honorary Members	9			
	Died	1			
		—	8		
	Elected:				
	March	1	1		
			—		9
January 1, 1923.	Total Members		738		
	Withdrawals:				
	Resigned	22			
	Dropped	48			
	Died	9			
		—	79		
			—	659	
	Elected:				
	January	4			
	February	5			
	March	1			
	April	7			
	June	3	20		
		—			
	Reinstated:				
	Resigned in 1919	1			
	Resigned 1921	1			
	Dropped in 1918	1			
	Dropped in 1922	2			
	Resigned in 1923	1			
		—	6		
			—	26	
				—	685
January 1, 1913.	Total Associates		78		
	Withdrawals:				
	Dropped	6	6		
			—	72	
	Elected:				
	June	2	2		
	Reinstated:				
	Resigned in 1916	1	1		
			—	3	
				—	75
September 1, 1923.	Total membership				769
January 1, 1923.	Total membership				825
	Net loss				56

Members Elected from January 1, 1923, to September 1, 1923.

January. Arthur L. Gammage, Walter F. Garland, E. C. Hopkins, Thomas W. Proctor. (4)

February. Dexter P. Cooper, Charles E. Kendall, Harry N. Lendall, Daniel M. Sullivan, George G. Weeks. (5)

March. Harry E. Holmes. (1)

April. N. J. Beisel, Harold C. Chandler, Harry T. Foley, Frank Hartman, R. W. Hendricks, George O. W. Servis, Robert L. Totten. (7)

June. Martin G. Ferry, Thomas Hersom, Jr., William P. Melley. (3)

Reinstated:

Dropped in 1918, George A. Stowers	1
Dropped in 1922, Samuel A. Agnew and Earle Talbot	2
Resigned in 1919, Horace J. Cook	1
Resigned in 1921, James H. Mendell	1
Resigned in 1921, J. Frank Ellis	1
	6

Associates.

June. Lap-Joint Impervious Pipe Co.; McWane Cast Iron Pipe Co. (2)

Reinstated:

Resigned in 1916, Ware Coupling and Nipple Co. (1)

Honorary Member.

Died: Rudolph Hering. (1)

Members.

Died: David Dexter Clarke, Frank E. Hammond, Frank W. Hodgdon, Louis H. Knapp, William H. Pitman, William D. Pollard, James T. Stevens, Herbert M. Tucker, Henry A. Young. (9)

Resigned: Forrest E. Bisbee, J. H. Bridgers, Walter I. Brown, Guy Eldredge, Ivan Escott, Timothy E. Hopkins, William F. Hunt, T. J. McCarthy, Henry Newhall, Harold S. Palmer, Henry E. Perry, Charles E. Perry, William E. Perry, William J. Roberts, F. W. Schwartz, Arthur H. Smith, Charles H. Smith, T. V. Sullivan, Russell Suter, Arthur S. Tuttle, L. C. Wright, Adolph V. Zehr. (22)

Dropped: A. D. Adams, G. M. Bacon, C. H. Bartlett, C. S. Beaudry, C. A. Bingham, C. P. Birkinbine, S. W. Borden, Philias Brunelle, F. L. Cole, G. W. Cutting, Ernest Drinkwater, Edmund Dunne, B. R. Felton, C. H. Fischer, W. D. Frederick, W. E. Fuller, P. T. Gray, G. G. Hare, W. H. Jackson, H. R. Johnson, W. A. Keene, J. F. Kidder, H. C. Kinney, J. S. Langthorn, E. J. Looney, W. E. McDonald, Charles McLenna, A. M. McKenzie, Henry Manley, L. P. Marshall, S. J. Mason, E. L. H. Meyer, C. W. Mills, A. J. Mylrea, E. B. Norton, M. S. O'Leary, W. J. Orchard, W. H. C. Ramsey, F. H. Robbins, S. A. Sewell, F. N. Strickland, A. H. Sutherland, D. H. Townley, H. R. Turner, Morrell Vrooman, F. O. Walker, N. M. West. (48)

Associates.

Dropped: Allen & Reed, Inc., American Manganese Co., East Jersey Pipe Corp., Lock Joint Pipe Co., Robert Filter Mfg. Co., Van Gilder Water Meter Co. (6)

Honorary Member.

March. John Ripley Freeman (elected). (1)

Receipts from January 1, 1923, to August 31, 1923.

Initiation fees			$116.00
Annual Dues:			
Members	$3 943.09		
Associates	1 460.00		
		$5 403.09	
Fractional Dues:			
Members	$34.00		
Associates	10.00		
		44.00	
Past Dues	$14.00	14.00	
Total Dues			$5 461.09
Advertisements			2 589.00
Subscriptions			212.00
JOURNALS sold			149.75
Sundries			111.94
Total			$8 639.78
There is due the Association:			
Advertisements			$43.00
JOURNALS			6.25
Reprints			119.60
Subscriptions			8.00
Total			$8 816.63

FRANK J. GIFFORD, *Secretary.*

REPORT OF THE TREASURER.

January 1, 1923 to August 31, 1923.

CLASSIFICATION OF RECEIPTS AND EXPENDITURES.

Receipts.

Dividends and interest		$187.89
Initiation fees	$116.00	
Dues	5 461.09	
Total received of members		5 577.09
Received from Estate of Hiram F. Mills		517.50
JOURNAL:		
Advertisements	$2 589.00	
Subscriptions	212.00	
JOURNALS sold	149.75	
Sale of reprints	31.00	
Total received from JOURNAL		2 981.75

Miscellaneous:		
Sale of "Pipe Specifications"	$11.75	
Membership lists	3.00	
Certificates of membership	21.00	
Interest (Old Colony Trust Co.)	5.02	
Index	1.00	
June outing	8.00	
Cuts	20.00	
Meter rate sheets	1.00	
Postage (From Affiliation)	10.17	
Total		80.94
Total receipts		$9 345.17

Expenditures.

JOURNAL:		
Advertising agent's commission	$245.20	
Plates	871.59	
Printing	1 987.65	
Editor's salary	225.00	
Reporting	104.04	
Advance reports	56.50	
Reprints	439.10	
Stationery and postage	86.59	
Miscellaneous	5.71	
		$4 021.38
Office:		
Secretary's salary	$133.33	
Affiliated Societies	985.06	
Secretary's expense	19.63	
Assistant Secretary's expense	16.63	
Printing, stationery, and postage	113.14	
Membership lists	16.00	
		1 283.79
Meetings and Committees:		
Stereopticon	$14.50	
Dinners for guests	17.00	
Music at dinners	32.50	
Printing, stationery, and postage	147.12	
		211.12
Treasurer's salary	$33.33	
Certificates of membership	7.50	
Miscellaneous	39.50	
Exchange	.45	
		80.78
Total expenditures		$5 597.07

FREDERIC I. WINSLOW, *Treasurer*.

In account with the New England Water Works Association.

RECEIPTS.

1923.			
Jan. 1.	On hand (includes Lake Shore & Michigan Southern bonds)		$5 581.61
	Received from Secretary		8 639.78
	Interest on bonds and deposits		187.89
	Estate of Hiram F. Mills		517.50
			$14 926.78

EXPENDITURES.

Bills paid		$5 597.07
ON HAND.		
Framingham National Bank	$1 511.14	
Liberty Trust	1 765.94	
Franklin Savings, Boston	1 000 00	
Farmers & Mechanics Savings, Framingham	1 521.25	
People's, Worcester	1 466.53	
Mechanics, Reading	249.85	
Bonds Nos. 2642 and 2644 Lake Shore & Michigan R. R. 4s, due May 1, 1931	1 815.00	
		$9 329.71
		$14 926.78

ASSETS AND LIABILITIES.

ASSETS.

Cash in Banks		$7 514.71
Lake Shore & Michigan Southern bonds (above)		1 815.00
Accounts receivable:		
Advertisements	$43.00	
JOURNALS	6.25	
Reprints	119.60	
Subscriptions	8.00	
		176.85
		$9 506.56

LIABILITIES.

Surplus	$9 498.11
Bills payable	8.45
	$9 506.56

FREDERIC I. WINSLOW, *Treasurer*.

Report of Auditing Committee.

We have examined the accounts of the Secretary and the Treasurer of the New England Water Works Association, and find the books correctly kept, and the various expenditures of the past eight months proven by duly approved vouchers. The Treasurer has also accounted to us for the investments and cash on hand, as submitted in the above reports.

A. R. HATHAWAY,
E. D. ELDREDGE,
Finance Committee.

Report of the Editor.

To the New England Water Works Association: I present the following report for the Journal of the Association for the March and June issues of 1923. This report covers the total charges and accounts receivable relative to the above issues and is required at this time because of the change in the fiscal year.

The accompanying tabulated statements show in detail the amount of material in these Journals or partial volume.

Size. — The numbers contain 328 pages.

Reprint. — Fifty reprints of each paper have been furnished to the author where desired.

Circulation. — The present circulation of the Journal is:

Members, all grades	769
Subscribers	98
Exchanges	14
Total	881

A loss of 50 since December, 1922. Journals have been sent to all advertisers.

Advertisements. — There has been an average of 36 pages of paid advertisements with an income of $1 661.50, an increase of $91.00 over the average of two issues of 1922.

Pipe Specifications. — During the year the specifications for cast-iron pipe to the value of $4.00 have been sold, and payment received of $7.75 for specifications sold in 1922, but not noted in Editor's report for last year. The net gain by actual receipts up to December 31, 1922 was $343.35, so that total net gain from this source to date is $355.10 and 4 copies on hand, $1.00 worth if sold at retail.

Post Office Account. — The Association has a credit of $2.38 at the Boston Post Office, being the balance of money deposited for payment of postage.

TABLE 1.

STATEMENT OF MATERIAL IN MARCH AND JUNE, 1923, ISSUES OF THE JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

Date.	Pages of								
	Papers.	Proceedings.	Total Text.	Index.	Advertisements.	Cover and Contents.	Insert Plates.	Total	Total Cuts.
March	111	21	132	..	41	4	0	177	10
June	100	6	106	..	41	4	0	151	33
Total	211	27	238	..	82	8	0	328	43

TABLE 2.

RECEIPTS AND EXPENDITURES ON ACCOUNT OF MARCH AND JUNE, 1923, ISSUES OF JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

Receipts.		*Expenditures.*	
Advertisements	$1 674.50	Advertising agent's salary and commissions	$165.20
Sale of JOURNALS	149.75	Plates	113.86
Sale of Reprints	31.00	Printing	1 686.29
Subscriptions	212.00	Reporting	104.04
Cuts	20.00	Mailing-Postage	40.35
Index	1.00	Editor's salary	150.00
	$2 088.25	Editor's incidentals	23.30
	341.14	Reprints	120.60
		Wrapper	25.75
	$2 429.39		$2 429.39

HENRY A. SYMONDS, *Editor.*

TABLE 3.

COMPARISON BETWEEN MARCH AND JUNE, 1923, ISSUES OF THE JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

	Vol. XXVII. 1913.	Vol. XXVIII. 1914.	Vol. XXIX. 1915.	Vol. XXX. 1916.	Vol. XXXII. 1918.	Vol. XXXIII. 1919.	Vol. XXXIV. 1920.	Vol. XXXV. 1921.	Vol. XXXVI. 1922.	March and June issues of Vol. XXXVII 1923.
Average edition (copies printed)	1 000	1 050	1 325	1 500	1 388	1 200	1 150	1 100	1 100	1 100
Average membership	745	803	904	1 002	954	902	885	864	826	797
Circulation at end of year	858	951	1 079	1 155	1 010	1 002	970	929	929	881
Pages of text	554	564	596	538	398	566	359	399	618	238
Pages of text per 1 000 members	746	702	659	538	417	627	406	462	748	298
Total pages, all kinds	733	719	776	707	557	726	520	560	801	328
Total pages per 1 000 members	984	895	859	707	584	805	588	648	970	412
GROSS COST:										
Total	$3 586.29	$3 345.87	$4 243.35	$3 386.63	$3 115.00	$4 967.99	$5 011.03	$5 381.84	$6 354.10	$2 429.39
Per page	4.89	4.65	5.47	4.79	5.59	6.84	9.64	9.61	7.93	7.41
Per member	4.81	4.17	4.68	3.38	3.26	5.51	5.66	6.23	7.69	3.05
Per member per 1 000 pages	6.46	5.80	6.02	4.79	5.85	7.59	10.88	11.12	9.60	9.29
Per member per 1 000 pages text	8.68	7.39	7.85	6.30	8.19	9.74	15.77	15.61	12.47	12.81
NET COST:										
Total	$1 322.90	$1 155.33	$1 091.09	$1 171.98	$694.54	$2 675.04	$1 722.14	$1 869.85	$2 434.26	$341.14
Per page	.80	1.61	2.70	1.65	1.25	3.68	3.31	3.34	3.04	1.04
Per member	1.78	1.44	2.32	1.17	.73	2.97	1.95	2.16	2.95	.43
Per member per 1 000 pages	2.42	2.00	2.98	1.65	1.31	4.09	3.75	3.87	3.68	1.30
Per member per 1 000 pages text	2.42	2.38	3.88	2.17	1.83	5.25	5.43	5.43	4.77	1.80

President's Address.

Mr. Percy R. Sanders. Gentlemen: You have listened to the reports of the secretary, the treasurer and the editor for the eight months ending September 1, 1923.

By the secretary's report you will note that our total membership is 768, composed of 9 honorary members, 684 members and 75 associate members. We have lost by death, 1 honorary member and 9 members. We have lost by resignation, 22 members; 49 have been dropped for nonpayment of dues and 6 associates have been dropped for the same reason. These resignations and withdrawals may be traced in most cases to a transference of activities to some other line of work. By death, resignation and withdrawals, our net loss is 57.

Beginning with June 1, 1923, we started on our second year as a member of the Affiliated Technical Societies of Boston. This Affiliation is composed of the following societies:

Boston Society of Civil Engineers,
New England Water Works Association,
Plant Engineers Club,
Boston Section American Institute of Electrical Engineers,
Boston Section American Society of Mechanical Engineers,
Northeastern Section American Society of Civil Engineers,
Boston Section American Institute of Mining and Mechanical Engineers,
Massachusetts Chapter American Society of Heating and Ventilating Engineers,
Boston Chapter American Association of Engineers.

The Affiliation has its chairman, two vice-chairmen, treasurer, clerk and an executive secretary. It also has a council consisting of two members from each organization.

A review of just what membership in this Affiliation constitutes may be of interest to our members, and as we closed our first year on May 31, we can give concrete figures pertaining to the expenses of the New England Water Works Association membership in the Affiliation.

Prior to June 1, 1922, the affairs of our Association were conducted practically as they are at present with the exception of the office of secretary. The headquarters of the Association were in Tremont Temple for which a rental of $750 per year was paid. An assistant to the secretary was employed at an annual salary of $1 200 who devoted her entire time to the work of the New England Water Works Association. The average yearly expense of these two items will be seen to have been $1 950.

Upon becoming a member of the Affiliation, headquarters were continued as before in Tremont Temple, but the assistant to the secretary ceased to be an official of our Association and became a clerk of the Affiliation. Provision was made for the payment of rent and clerical work in the form of an assessment of $3 per member. If any member of the Association was also a member of any of the other affiliated organizations, the dues were allocated in proportion to his membership.

For the year ending May 31, 1922, the amount paid the Affiliation was $1 982.96.

Our membership January 1, 1917, was 1 043; September 1, 1923, or nearly seven years later, it is 768, a loss of 275 members.

Our need is new members to take the places of those who have dropped out by reason of death, resignation or otherwise, and the question is, how are they to be secured?

At the close of this convention, we start out with a new constitution which, while not differing materially from our former one, still makes some changes. The executive force is reduced, and the year, instead of beginning January 1 and closing December 31, will begin at the close of the annual convention, continuing until the close of the next.

This brings forward the thought, has not the time arrived when the several paid officers of this Association should be combined into one, whose incumbent would devote his entire time and energies to the welfare of the New England Water Works Association? I believe that a committee should be appointed to consider this matter thoroughly and make such recommendations as it thinks advisable.

I wish to thank the officers and members of the Association for their assistance and coöperation during the year and also the members and friends who have furnished the papers for our meetings. The printed record of our papers and discussions will always be a source of gratification to me and will recall memories of strengthened friendships and pleasant labors.

EDWARD JAMES CHADBOURNE.

EDWARD JAMES CHADBOURNE was born in Wiscassett, Maine, October 5, 1848, and died September 17, 1922.

He was educated at Oak Grove Academy, Vassalboro, Maine, and at Kent's Hill Seminary, Maine.

He joined the New England Water Works Association on June 11, 1885.

He superintended the construction of the Hingham and Nantasket, Spencer, Wakefield and Stoneham Water Works Systems. He later acted as superintendent of Water Works for Holbrook and Randolph, also Wakefield and Stoneham.

He was associated with the Coffin Valve Company of Neponset for over fifteen years.

At the time of his decease he was senior member of the firm of Chadbourne-Walker Machine Screw Co., 100 Sudbury Street, Boston, and resided at 6 Walnut Street, Reading.

He married Sarah A. Beless of Needham, May 14, 1873. Two daughters survive him, Mrs. Arthur L. Wiley of Wakefield, Mass. and Mrs. Edward H. Sawyer of Cambridge, Mass., and one grandson, Arthur Lyman Wiley, Jr.

Mr. Chadbourne pursued a very varied and active life. He accomplished much in the line of Water Works construction. Manufacturing also appealed to him very strongly. He was an honest, able man, respected and highly esteemed by all who had the good fortune to know him.

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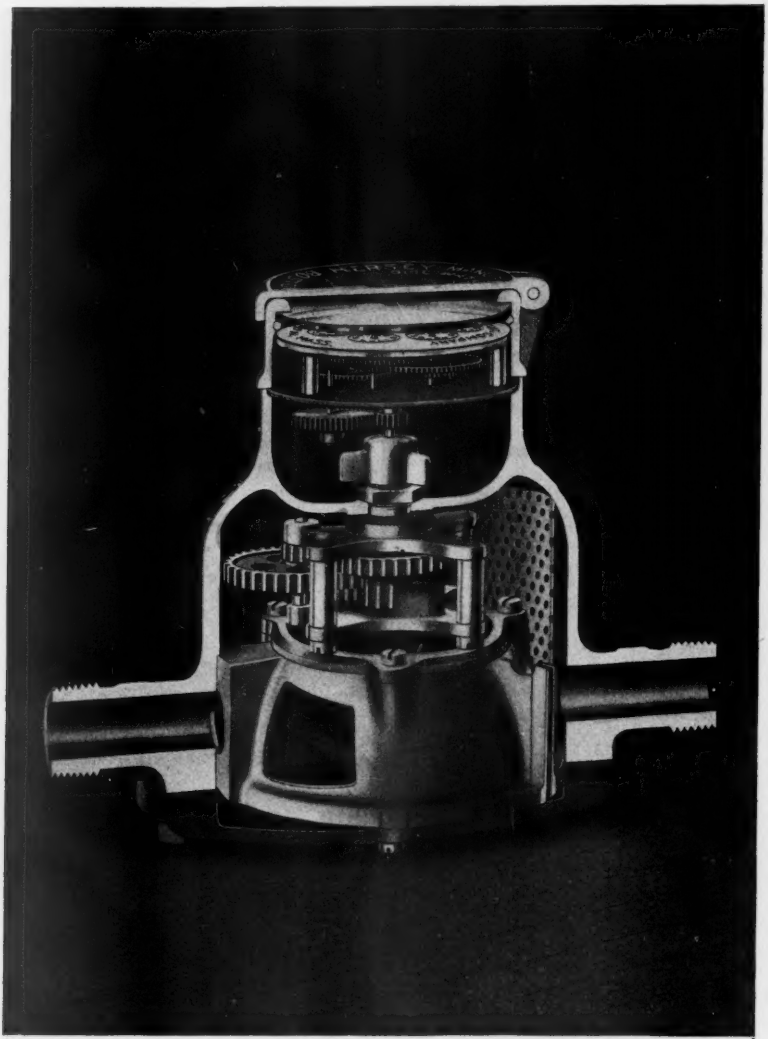
\$.75
Dear Sir: Enclosed please find 1.50 in payment of charge for Certificate
2.25
of Membership in the N. E. W. W. Association (\$1.50), and Membership Button (\$ .75), which please mail me and oblige

Yours truly,

_____



HERSEY DISC METER, MODEL HF, which is the highest type of Frost protected Meter and HERSEY DISC METER, MODEL HD, which is the highest type of divided or split-case Meter, are the product of thirty-five years' experience and refinement in the manufacture of Water Meters. These Models excel all Meters of all makes in all those essentials which go toward making exceptionally desirable Meters.

HERSEY MANUFACTURING COMPANY

Main Office and Works: E and 2d Sts., SOUTH BOSTON, MASS.

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FROZEN!—but not damaged

Here is an actual photograph of a LAMBERT Frost-proof Meter which has been frozen to an extent that would put the ordinary meter completely out of commission.

This is made possible by a patented, non-corrosive yielding bolt device which allows the upper and lower casing, disc chamber and gear train to part without damaging the meter in any way. Five minutes' labor the only repair cost.

The expense and annoyance from frozen water meters can be eliminated for all time through the installation of the LAMBERT Frost-proof.

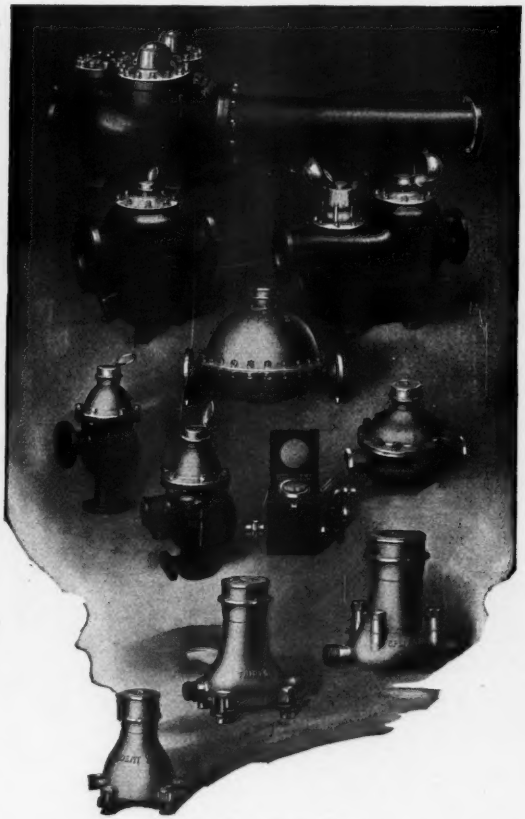
It has been proved that the LAMBERT is the easiest water meter to take apart and put together again as well as the simplest, most reliable and accurate.

If you are interested in other types of meters, we make one for every requirement.

THOMSON METER COMPANY

100-110 BRIDGE STREET BROOKLYN, N. Y.

LAMBERT FROST-PROOF METERS



A Trident for Every Service!

WHY are there more than two million TRIDENTS in service?

There is only one reason,—TRIDENTS are more continuously accurate, more durable, more economically maintained. They are the *best* meters. Don't stint quality—you need the best for *your* services!

Have you seen our latest development,—the Trident (enclosed) Gear Train?

NEPTUNE METER COMPANY

50 EAST 42d ST., NEW YORK CITY

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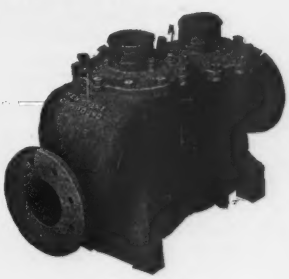
WATER METERS

ARCTIC—*a frost-bottom meter for Domestic Services.*

KEYSTONE—*an all bronze meter for Domestic Services.*

EUREKA—*a current meter for large and rapidly flowing volumes of water.*



KEYSTONE-COMPOUND—*for services requiring accurate measurement of small as well as large volumes of water.*

PITTSBURGH METER COMPANY

East Pittsburgh, Pa.

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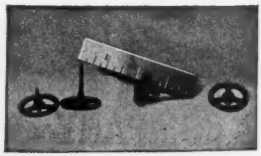
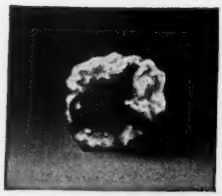
What Freezing Did Not Do

These two pictures show the intermediate gears of a Worthington Model "G" Meter. In one the train is encased in a solid block of ice, just as the parts were taken out of a completely frozen meter. After the ice melted the other photograph was made to show that no damage was done. Gears, train plate and casing, all came through the freezing totally unharmed. The only parts which suffered were four little bronze frost clamps, replaceable for a few cents. This shows some of the things that do *not* and *cannot* happen when a Worthington meter freezes. Those little frost clamps are certainly cheap insurance against the ravages of zero weather.

WORTHINGTON



Showing the gears, pinions and train plate after thawing. Not a single part has been warped or distorted in the least. The straight edge across the face of the train plate shows clearly that the original shape has not changed.



The intermediate train just after it was taken out of a standard Worthington meter. Note how completely the gearing is encased in ice.

WORTHINGTON PUMP AND MACHINERY CORPORATION

Executive Offices: 115 Broadway, New York City

Branch Offices in 24 Large Cities

WHILE THE TRENCH IS OPEN

is the time to install Venturi Meter Tubes in the pipe line, whether it is new construction or repairs and changes to old lines. Much expense and inconvenience is saved by doing the whole job at one time.

VENTURI METERS

Should be placed in every main pipe line of every water works system. Practically all large cities of the United States and Canada have accepted the above statement and adopted it as standard practice for both pumping lines and gravity mains. They realize it is just as important to meter main supply lines as to meter individual services to users. The cost of a Venturi Meter Tube is not greatly in excess of the straight pipe it replaces and the friction loss is negligible. If you contemplate new work or repairs why not put in Venturi Meters now? You will eventually.

Send for Bulletin No. 210

Builders Iron Foundry

PROVIDENCE, R. I.

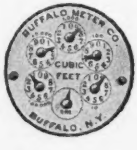
AMERICAN AND NIAGARA WATER METERS

5/8 INCH NEW AMERICAN WATER METER

5/8 INCH NEW NIAGARA WATER METER

Niagara and American Meters are of the disc type. The Niagara Meter has a galvanized cast-iron outside casing; the American Meter has a bronze main casing with either a bronze base or a galvanized cast-iron base. The works in the three different casings are the same and interchangeable. Upon opening the meter at the bolted flange, each intermediate gear may be immediately removed from its bearing, the measuring chamber lifted from its seat, the strainer slipped out, or the register tried by turning the stuffing box gear. All submerged working bearings are protected against sand and sediment. The hard rubber measuring disc is reinforced with a metal plate. Purchaser has option of round reading or straight reading register indicating cubic feet, U. S. gals., imp. gals. or litres.

Round Reading Register

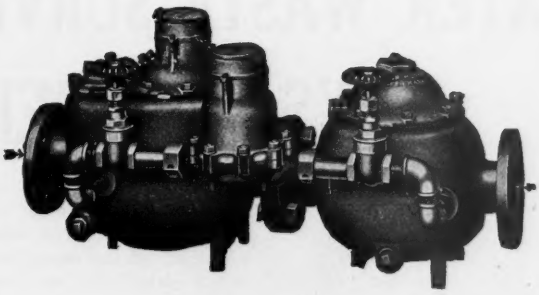


Straight Reading Register

BUFFALO METER CO.

ESTABLISHED 1892

2896 Main Street BUFFALO, N. Y.



The New Nilo

The new improved **Nilo Compound Meter** now comes equipped with a bronze body. This is a valuable addition to meter service for it eliminates the danger of corrosion and filling up due to the collecting of corrosive matter. Bronze being stronger than iron the gross weight of the meter is less, making it easier to transport, handle and install.

It also has two gate valves which allow the removal of the by-pass meter for cleaning or repairing without shutting off the line.

The controlling valve mechanism of the new **Nilo Compound Meter** is self contained and easily detached from the main body casings.

These three improvements make the **Nilo,** a long standing favorite, the unrivaled leader in its field.

UNION WATER METER CO.

Incorporated 1868

WORCESTER, MASSACHUSETTS

WATER WASTE SURVEY
PAYS for ITSELF

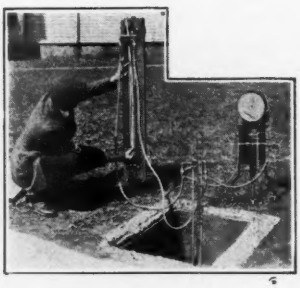
Every water waste survey thus far made by the Simplex Valve & Meter Company has revealed a waste of water, the cost of delivering which for one year has far exceeded the total charge for making the survey.

Simplex water waste surveys check up the performance of your pumps, the registration of your meters and through subdividing the distribution system into districts, locate leaks in mains or house services, broken mains, blown joints and other losses.

The organization of the Simplex Valve & Meter Company includes a corps of engineers thoroughly experienced in this work and their services as well as the use of the Simplex water waste instruments are at all times available for the use of water departments and water corporations.

SIMPLEX VALVE & METER CO.

5729 RACE STREET, PHILADELPHIA, PA.



A Simplex Pitot tube recorder set up over a water main for testing flow during water waste survey.

"WATCH DOG" WATER METERS

ACCURATE *DURABLE*

DISC, CURRENT AND COMPOUND TYPES

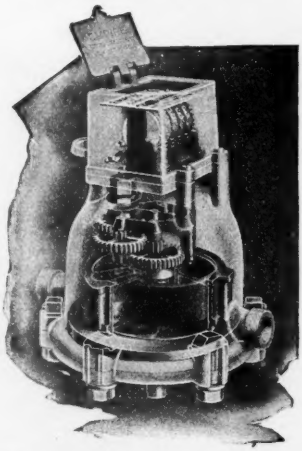
Inquiries Solicited

GAMON METER COMPANY

NEWARK **NEW JERSEY**

Something To Remember

The initial cost of any water meter is only paid once, but the maintenance cost goes on as long as the meter is in service. A meter that **stays** accurate, and keeps pulling in the revenue, year in and year out, with minimum stoppages or repairs, is the only economical one to buy.



The EMPIRE

has a fine record for that sort of work. It is practically in a class by itself for sustained accuracy, and endurance, and second to none for all round excellence. The initial cost of an **Empire** seems ridiculously low when compared to its high earning powers, its small maintenance expense and its long life.

What "They Say" About It

This is from a letter written by an official who has used **Empire** meters for over 20 years:

"We find **Empire** meters to be simple, accurate, and reliable, and the cost of upkeep less than any other make we have in use, and we have in service today nearly all makes." . . . "They prove to be the most economical in service of any meter we have, earning their cost in increased revenue many times over."

Send for descriptive literature and prices.

NATIONAL METER COMPANY

299 BROADWAY, NEW YORK

Chicago, Ill.: 1455 West Congress St. San Francisco, Cal.: 141 New Montgomery St.
Los Angeles, Cal.: 251 Central Ave. Boston, Mass.: 287 Atlantic Ave.
Cincinnati, O.: 530 Reading Rd. Atlanta, Ga.: 253 Ivy St.
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ATTENTION
WATER WORKS
OF NEW ENGLAND

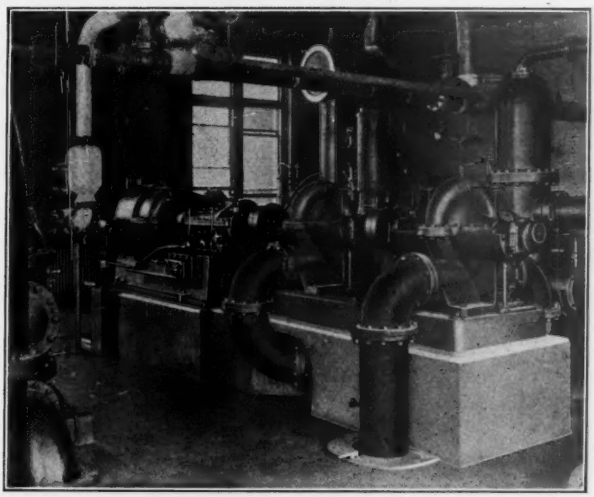
A few reasons why we solicit your inquiries on Water-Works Pumping Equipment:

First. — We make a specialty of furnishing Complete Water-Works Pumping Units of all types.

Second. — Total responsibility of installation is assumed by us.

Third. — We relieve the purchaser of every detail and turn the complete unit over to him under actual operation and with guarantee.

Fourth. — Every unit installed to date has exceeded its guarantee and has been completely accepted.



Turbine-driven Pump at the Arlington Station of the Metropolitan Water Works, Boston, Mass.

F. A. Mazzur & Co.

141 MILK STREET, BOSTON

FIFTY MILLION GALLON LOW LIFT PUMPING ENGINE

This Unit Is On Order For The Metropolitan District Commission, Ward Street Sewerage Station, Boston.

F. D. SMITH, Chief Engineer

DATA

35,000 gallons per minute capacity against 45 feet head.

Morris Machine Works Centrifugal Pump 36″ discharge, 40″ suction.

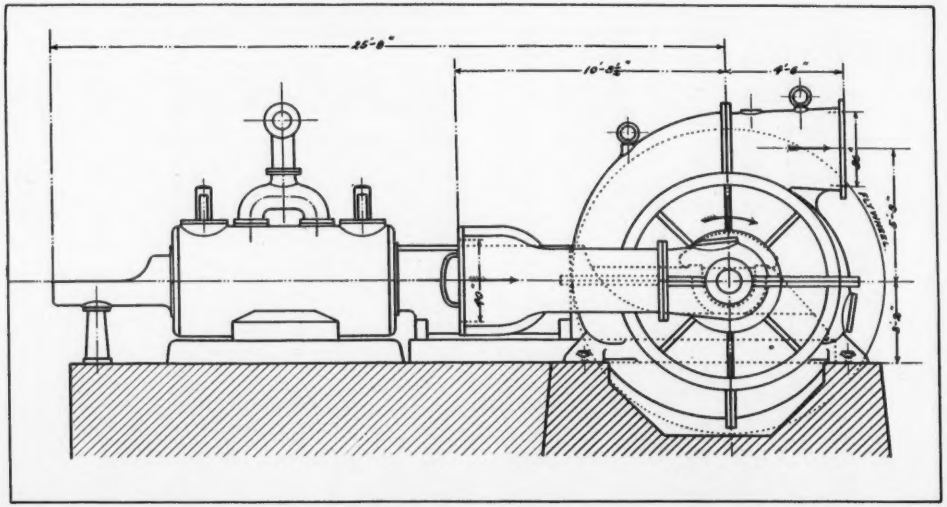
Nordberg Mfg. Co.'s Uniflow Engine, Cylinder 24″x 40″ at 150 r.p.m.

Steam Conditions 150 lbs. gauge 26″ vacuum, 1½% moisture.

Duty Guarantee 105,000,000 foot pounds per 1000 pounds steam.

Total Weight 130 tons = 2.6 tons per million gallons.

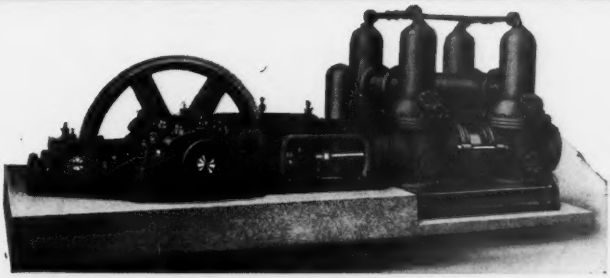
Cost of Pumping: $1.81 per million gallons pumped (steam costing 50c per 1000 lbs.).



There are many New England Waterworks having boilers for existing pumps where a similar unit would show superior economy.

STARKWEATHER & BROADHURST, Inc.

ENGINEERS AND CONTRACTORS **79 MILK STREET, BOSTON**



PLANT EFFICIENCY—77% ON 1-YEAR RUN
WIRE TO WATER

HAYES PUMP AND MACHINERY CO.

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CENTRIFUGAL, POWER, STEAM PUMPS

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WATER WHEELS

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OIL ENGINES

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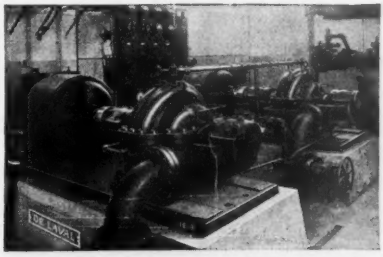
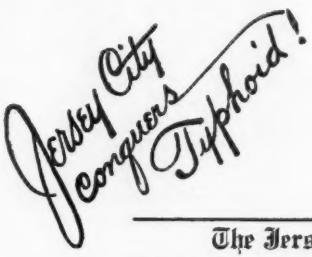


Typical Small Electrically Operated Centrifugal
Municipal Water Works Installation.

POWER EQUIPMENT COMPANY
BOSTON



The Jersey Journal

CITY REMARKABLY FREE FROM TYPHOID

In 1922 Death Rate Was Only 1.9 Per 100,000 Population—Expect to make Third or Fourth Place in Whole U. S.

Jan. 18, 1923 — The death rate from typhoid fever in Jersey City last year was only 1.9 per 100,000 population; there were only 18 cases in the city throughout the year and only 6 deaths, said Dr. George McLaughlin, bacteriologist for the Jersey City water supply, today. Dr. McLaughlin received his figures from the report of the State Board of Health, which covers every municipality in the state.

In 1891 the death rate from typhoid in Jersey City was 102 per 100,000 population. This was when Jersey City used the old Passaic River water supply.

In 1919, when so many of the city's young men were away to war, the death rate from typhoid in Jersey City was only 1.5 per 100,000 population. That was the lowest death rate in the history of the city, but the rate of 1.9 per 100,000 in 1922 is very little higher and is really a better showing, Dr. McLaughlin said considering the greatly increased population.

In fact, the figures of this report show that Jersey City stands third or fourth among all the cities of the United States in healthiness, as far as typhoid fever is concerned, **Dr. Laughlin said, and this is due to the purity of the city's present water supply from the Boonton reservoir**

because Jersey City uses W & T Apparatus to sterilize its water supply with Liquid Chlorine. So do nearly 3000 other communities in the U. S.

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COMPANY INCORPORATED

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WALLACE & TIERNAN, LTD., TORONTO

Health and Protection First

Water delivered through dirty pipes
may be a MENACE.

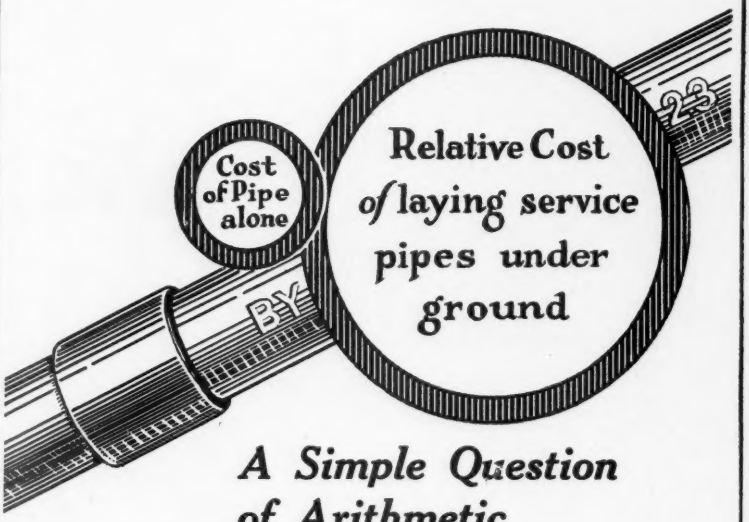
Incrusted water pipes mean inefficiency
and loss of Fire Protection.

We Guarantee the Results of Our
Method of Cleaning.

WRITE US.

National Water Main Cleaning Co.

50 Church Street New York City



A Simple Question of Arithmetic

The cost of a length of service pipe is trifling compared with the cost of laying it. In case of failure of the pipe, the loss of water, labor of digging up and renewing a pipe, still further multiplies the installation cost.

The lasting quality of the pipe, depending on its rust-resistance, is therefore the first thing to be considered by the majority of experienced water works engineers and superintendents. Hence the extensive use of Byers pipe for underground water service.

The chemical and physical properties of genuine wrought-iron and their bearing on the question of rust-resistance, are interestingly dealt with in Byers Bulletin No. 6-A. Write to A. M. Byers Company, Pittsburgh, Pa., for a free copy.

BYERS PIPE

GENUINE WROUGHT IRON

Look for the Name and Year rolled in every length

H. W. CLARK CO.
1740 Broadway Mattoon, Ill., U.S.A.
Branch Offices:
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Manufacturers of the well-known CLARK METER BOX, maintaining uniformity for both large and small meters. Standardization in meter installations saves you money. Everything for the Water Works.
Write for new catalogue No. 20.

GEO. E. GILCHRIST CO.
Manufacturers and Jobbers of
Steam, Gas and Plumbing Materials
WROUGHT IRON PIPE
Railway, Water Works and Sanitary Supplies
106 High, corner Congress St., Boston

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CAST IRON BELL AND SPIGOT WATER PIPE AND FITTINGS
FLANGED PIPE in full and short lengths
WROUGHT PIPE
FRED A. HOUDLETTE & SON
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Quotations furnished promptly for shipment from Foundry

BRAMAN, DOW & CO.

NATIONAL STEEL PIPE
READING IRON PIPE
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"CALDWELL" WATER WORKS BRASS GOODS AND CURB BOXES
NONE BETTER AND FEW AS GOOD
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REDUCING, REGULATING & RELIEF VALVES
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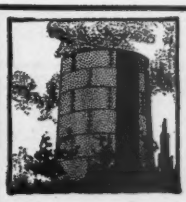

Standpipes
Water Tanks
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and all other metal surfaces need the protection of
DIXON'S
Silica-Graphite
PAINT
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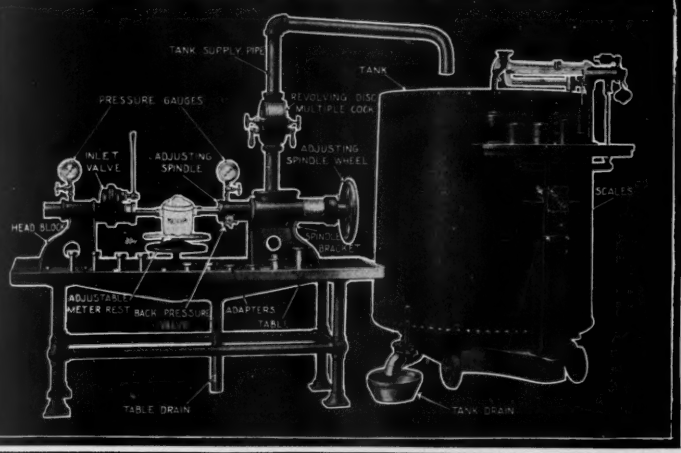
JOSEPH DIXON CRUCIBLE CO. Jersey City, N. J.



The People Demand Increased Efficiency

You can make sure your Department gets full revenue for every gallon of water used—by seeing that all meters are regularly tested for accuracy—with the

Mueller Water Meter Tester

The Mueller will prove exactly what each meter does—will enable you to adjust each meter to absolute accuracy—will save more than its cost year after year. Used and endorsed by leading municipalities. The name Mueller guarantees both Quality and Service.

Detailed description and prices on request.

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Phone Bell 153—Auto 2131

Water, Plumbing and Gas Brass Goods

New York City, 145 W. 30th St. — Phone, Madison Square 5397
San Francisco, 589 Mission St. — Phone Sutter 3577

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R. D. WOOD & CO.

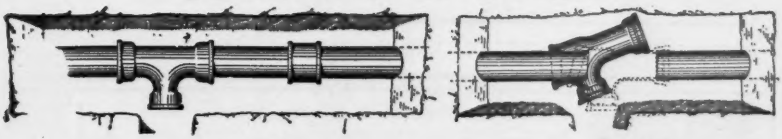
400 CHESTNUT STREET, PHILADELPHIA, PA.

Engineers, Iron Founders and Machinists

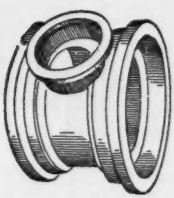
CENTRIFUGAL PUMPS
PUMPING ENGINES

Cast Iron Pipe

CUTTING-IN TEES



Old Way *Our Way*



Connections economically and easily made with one fitting. Saves sleeve, cuts, lead and unnecessary work and material.

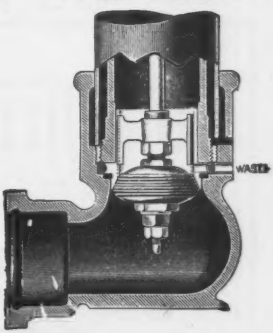
"Reduced Specials"

Cost of fittings reduced from 25% to 50%. Full strength. Deep bells. Convenient to handle. Sold by the piece.

Mathews Fire Hydrants

A half century of use has established their reputation as being the most economical, durable and simple hydrant.

Number in use exceeds total of all other makes combined.



Gate Valves

R. D. WOOD & CO. STANDARD
DOUBLE DISK
ANTI-FRICTION
EXTRA WEIGHT, FINISH
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Ware Coupling & Nipple Co.

WARE, MASS.

Grip Pipe Fittings and Brass Nipples

WATER
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We make **Pressure Regulating Valves** for all purposes, steam or water.

Our **Feed-Water Filter** will keep oil out of your boiler.

We can interest you if you use a condenser.

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THE ROSS VALVE MFG. CO.

TROY, N. Y.

Standard for pumping church or parlor organs. Ask your organ builder for it or write us.

Coffin Valve Co.

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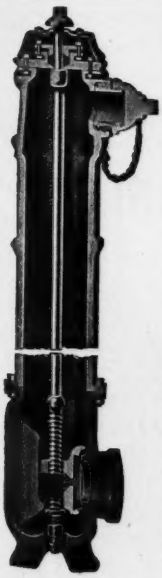
Sluice Gates, Gate Valves and Fire Hydrants



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VALVES and FIRE HYDRANTS

This hydrant is anti-freezing, because when the drainage is good no water is left in it to freeze.

The drip is directly in the bottom of the hydrant and drains perfectly. It is protected by its valve, which never leaves its socket and cannot be clogged.

DOUBLE AND SINGLE GATE **VALVES,**

ALSO CHECK **VALVES,**

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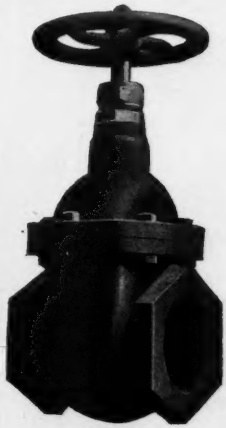

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Catalogue "F" for the asking

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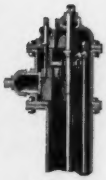
WATERFORD, NEW YORK U.S.A.

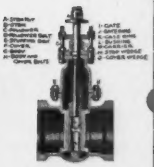
PATENT RUBBER FACED

EDDY FIRE HYDRANT

Section of Taper Seat-Valve.



Hydrant with Independent Nozzle Cut-off.



Section of Parallel Seat-Valve.

Section of Vertical Check-Valve.

Section of Vertical Foot-Valve.

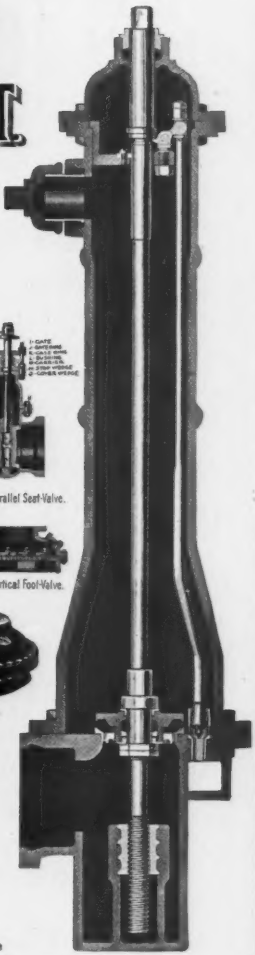
Horizontal Check-Valve.

Vertical Foot-Valve.

Hydrant with Water Crane Attachment.

Indicator Post.

Water Crane with Automatic Drip Valve.



VALVE OPEN—DRIP CLOSED.

All Goods made by the EDDY VALVE COMPANY are manufactured exclusively at WATERFORD, N.Y., U.S.A.

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DONALDSON IRON CO.,

MANUFACTURERS
...OF...

CAST IRON PIPE

...AND ..

Special Castings for Water and Gas.
Also Flange Pipe, Street Castings,
Manhole Heads and Covers, etc.

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Is your per capita consumption too high?

Do you account for less than 85% of your pumpage?

Are you receiving full revenue from your manufacturing consumers?

If any of these problems confront you, write us at once, without obligation, and let us tell you about our PITOMETER SURVEYS.

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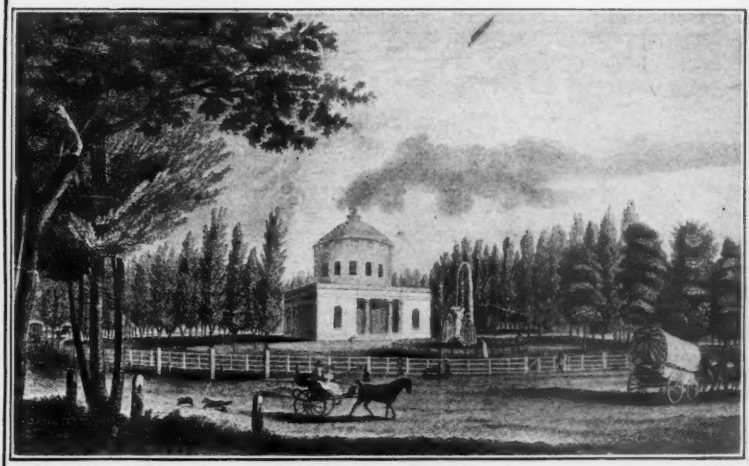
Philadelphia is most bountifully provided with fresh water, which is showered and jerked about, and turned on, and poured off, everywhere. The waterworks, which are on a height near the city, are no less ornamental than useful, being tastefully laid out as a public garden, and kept in the best and neatest order. The river is dammed at this point, and forced by its own power into certain high tanks or reservoirs, whence the whole city, to the top stories of the houses, is supplied at a very trifling expense.

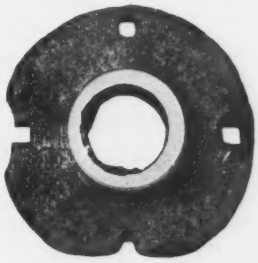
— "*American Notes*" *by Charles Dickens.*



Old Pumping Station, Philadelphia

In 1842 Charles Dickens wrote the above description of the Philadelphia Water Works. At that time cast iron pipe, in Philadelphia, had been delivering water faithfully for 25 years. Nor was its usefulness nearly over. In 1915 the pipe illustrated was removed, though still in good condition after almost a century of service, to make way for a line of larger capacity.

Write to the Publicity Department, Burlington, for booklet "98 Years of Excellent Service."



Section of 1817 line

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Manufacturers of

Tapping Machines, Fire Hydrants, Water Gates,

Economic Lead Furnaces,

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Also General Supplies for Water and Gas Works.

Write for Catalogue.

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Special Castings, Fire Hydrants, Valves

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NEW YORK CITY

HIGHEST AWARD, GOLD MEDAL,
ST. LOUIS EXPOSITION, 1904

Over 100 Water Departments

use

LEAD-LINED IRON and TIN-LINED PIPES

for their service connections

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Lead Lined Iron Pipe Company

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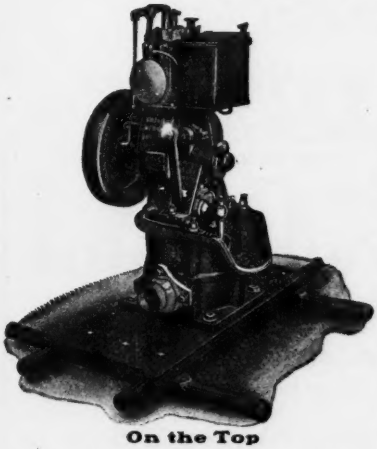
375 BROADWAY, BOSTON, MASS.



On the Top

NO. 1 AIR-COOLED GASOLINE ENGINE
Can be attached to any Diaphragm Pump

This Engine is built for Diaphragm Pumps by the makers and inventors of the Pump.

Fifty years' experience is behind it — reliable as the original pump you have known for years.

Now in use by many of the Water Departments.

Mounted on Skid or 4-Wheel Hand Truck, also either Battery or Magneto Ignition.

Warren Foundry and Pipe Co.

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Special Castings

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Twelve Reasons Why

YOU SHOULD USE

Trade "LEADITE" Mark

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FOR

Jointing Water Mains

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2. **NO CAULKING.** Leadite joints require no caulking, because the Leadite adheres to the pipe, making a water-tight bond.
3. **COMPARATIVE QUANTITIES.** One ton of Leadite is equivalent to four tons of lead.
4. **LABOR SAVING.** Saves caulking charges and digging of large bell-holes, and reduces the cost of trench pumping to the minimum.
5. **COST.** Its use saves 50 to 65 per cent. over lead, owing to the saving effected in material and labor.
6. **TOOLS.** As no caulking is required, fewer tools are needed.
7. **TRANSPORTATION.** Considerable freight charges are saved because Leadite is lighter than lead.
8. **HAULING.** Saves hauling expense on the work because you move only one fourth the weight of jointing material.
9. **FUEL.** Saves fuel because you melt only one ton of material instead of four, and not as much heat is required either.
10. **DELIVERY.** We can make prompt shipments.
11. **DAMAGE SUITS.** Claims for damages caused by joints blowing out are prevented because Leadite joints will not blow out under any pressure.
12. **USERS.** Progressive water works all over the country use Leadite.

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Chadwick-Boston Lead Co.

162 Congress St., Boston

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The Celebrated "ULCO"

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(Every Atom Pure Lead)

For calking pipe joints under the most difficult conditions.

For overhead joints, or in wet places where the use of molten lead is not only impracticable but dangerous — **LEAD WOOL** may be used to advantage.

It makes an absolutely tight joint which will withstand the highest pressure, yet be sufficiently elastic to allow considerable sagging or settling of the pipe without danger of a leak.

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PIG LEAD

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WITH

LEAD-HYDRO-TITE

TRADEMARK

AND CUT YOUR EXPENSES

50% FIRST COST

50% SMALLER BELL HOLES

75% HANDLING

100% CALKING

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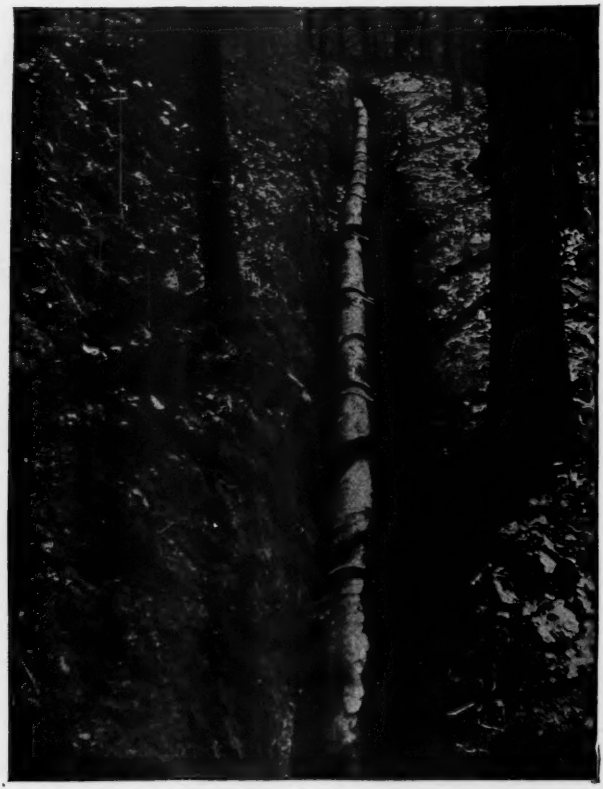

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giving perfect service
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no packing no calking no bell holes

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New England Water Works Association,

ORGANIZED JUNE 12, 1882.

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I, the undersigned, residing at .....

..... *being desirous of admission into the New England Water Works Association, hereby make application for* .....

(resident, non-resident or associate)

..... *membership.*

I am ..... *years of age, and I have been engaged in the following named work:*

.....

.....

.....

I will conform to the requirements of membership if elected.

Signed, ...

Address, ...

Dated, ... *19*

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